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RECENT PROGRESS IN THE CHEMISTRY OF THE PROTEINS.*

BY
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I. THE PROBLEM.

AMONG the natural albumins, and other proteins, the possibilities of intricate atomic linkage and of the resulting complex molecular structure have been realized more fully than in any other class of chemical compounds. This is evident from the magnitude of the molecular weight, which, for different proteins, varies from 15,000 to 25,000. These enormous figures are minima, since it is impossible to guarantee the purity of the substance used in the determination, and the observed minute changes in the freezing-points of solvents may well have been at least partially due to traces of other compounds. Lottermoser has found that after decomposing sodium silicate with hydrochloric acid, it is quite impossible to free the colloidal silica from absorbed salt and the difficulties in the way of depriv-

*Contribution from the Laboratory of the Southern High School.

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ing a substance like egg albumin of traces of crystalloidal matter are at least as great.

Clearly in a carbon compound with a molecular weight of 20,000 or so, the number of isomers due to variations of ordinary structure which may occur is practically infinite. But this is only half the story. All the proteins contain large numbers of asymmetric carbon atoms and, according to Van't Hoff's well-known law, this multiplies the number of structural isomers by 2^n where n is the number of such atoms.[1]

Looking at the matter from an entirely different viewpoint, we obtain the same impression of staggering complexity. The proteins occupy a peculiar place in nature. The rôle of the fats and carbohydrates is simple and can be filled by compounds of comparatively simple chemical character, but the rôle of the proteins can only be adequately played by a class of compounds capable of the greatest possible diversity of chemical structure and behavior. Aside from the familiar different functions which proteins have in different parts of the animal and plant body, it is becoming evident that the albumins of different species of animals—I mean those of similar function and character in the different species—are slightly but specifically different. So far as the proteins of the blood are concerned, the Bordet blood-test—developed by Uhlenhut and others into a forensic method of great importance—is a clear proof of this. Recent investigations of the milk of various mammals point in the same direction. In fact the whole trend of recent research is toward establishing the manifold possibilities of the proteins and the delicate and yet strictly specific nuances of chemical behavior which they exhibit.

It is not too much to say that the synthesis of this class of compounds by methods which give a complete account of their constitution is the most difficult task which has been set before the organic portion of our science. The difficulty reappears in practical work, for the proteins have some very undesirable laboratory attributes. Their characteristic instability, while most important in nature, is not helpful to the synthetic chemist,

[1] This does not hold good if it turns out that only one of each enantiomorphous pair is found in nature, as appears to be the case with the amino-acids.

and the impossibility of crystallizing most of them renders their purification especially difficult. In fact it is extremely doubtful whether any of them, with the possible exception of the albumins, are really chemical individuals.

On the other hand, those who endeavored to travel by the analytic road have met with insuperable difficulties. The only possibility is to break up the enormous molecule into simpler ones of known constitution and then to attempt to form some idea of the way in which the compounds obtained are united in the original substance. Of the various methods of attack, the only one which has given results of definite value is total hydrolysis by alkalies, acids, or ferments. This resolves the protein at once into its simplest proximate constituents, which, aside from ammonia and glucosamine, are exclusively amino-acids.

The next step is to separate these amino-acids from each other and to get at least an approximate idea of the quantity in which each is present. This, until Emil Fischer's ester method was discovered, was impossible. Some amino-acids, like leucine and tyrosine, are easily separated from the mixture obtained on hydrolysis by means of their difficult solubility in water. Glutaminic acid was detected on account of the slight solubility of its hydrochloride. The wide distribution of these acids in the various proteins investigated was at once recognized. But, for the majority of the amino-acids produced, suitable methods of separation and purification were unknown and they not only could not be estimated quantitatively but escaped observation altogether. In fact, by the total hydrolysis of the protein molecule a large number of decomposition products are formed whose properties are, in the main, very similar to each other. Many of the amino-acids form mix-crystals with each other. All the amino-acids which occur in the proteins are optically active and by the more or less violent methods of hydrolysis they are in part racemized. While the chemical properties of the racemic form closely resemble those of the active modifications, the physical properties, especially solubility, are so different that serious additional difficulties are thrown in the way of the separation.

2. TOTAL HYDROLYSIS—THE ESTER METHOD OF EMIL FISCHER.

The total hydrolysis of the proteins has been almost always carried out with 25 per cent. sulphuric acid or with concentrated hydrochloric acid. Six hours' boiling suffices in the latter case, while in the former sixteen hours is required. The acid is previously warmed upon the water-bath until complete solution results and the time required for this is not included in the above statement. Half a kilo of albumin is as much as can be profitably worked up in one operation. The result of the boiling is a dark violet or brown solution. It is filtered from any undissolved residue and the filtrate and wash-water evaporated together at a temperature not higher than 40° and a pressure of about 15 mm. to a syrup. This is taken up with a large quantity of absolute alcohol and hydrochloric acid gas led into the liquid in order to convert the amino-acids into their ethyl esters, which are, of course, obtained as hydrochlorides. Glycine can be removed at this stage by evaporating somewhat and adding a crystal of glycine ethyl ester hydrochloride. This whole series of operations, estrification by HCl, evaporation, and removal of glycine, should be repeated at least three times. Then the solution of the ester hydrochlorides can be evaporated to a syrup and the free esters liberated from the hydrochlorides by the addition of caustic soda and potassium carbonate. Since the saponification of the esters is to be avoided and some of them are very sensitive to alkali, this operation requires caution and skill.[2] The liquid should be cooled and covered with a layer of ether to remove the amino-acid-esters as fast as they are liberated from the hydrochlorides. From time to time the ethereal layer is poured off and immediately renewed. When the liberation is finished the whole ethereal solution is evaporated to remove the ether. Most of the ether can be safely removed by ordinary evaporation, but for the last portions it is best to use reduced pressure to avoid the loss of important quantities of the simpler esters, like those of glycine and alanine.

The amino-esters are then separated into fractions by dis-

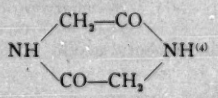
[2] It would exceed the scope of this paper to give all the details of Fischer's ester method, the publication of which marks an epoch in this domain. A full account can be found in Zeitschrift für physiolog. Chemie, vol. 33, p. 151, 1901. This paper is reprinted in Fischer's collected researches, p. 633. A briefer but very good description is given by Aberhalden (Eiweisschemie, p. 15, et seq., 1909).

tillation under greatly reduced pressure on the water-bath and finally on the oil-bath. No attempt is made to separate the individual acids in this way. That would be quite impracticable. But subdivision into four fractions only effects such a preliminary separation that the isolation of the individual acids can usually be carried out without too much difficulty.

3. THE AMINO-ACIDS.

The amino-acids are discussed in the text-books of the organic side of our science and, owing to their physiological importance, have received a rather full treatment, even in the briefer of the recent books.[3] It would be out of place to catalogue them in the present paper. It is desirable, however, to discuss very shortly two or three typical ones as examples of the substances of which the protein molecule appears to consist.

The simplest one is glycine, amino-acetic acid, NH_2CH_2-CO_2H. It has been known for nearly a century. It is widely distributed as a protein constituent and is readily obtained synthetically from mono-chlor-acetic acid and ammonia. It is interesting as being the only natural amino-acid which does not contain an asymmetric carbon atom. All of the other protein constituents are active and asymmetrically constituted. Either the dextro- or the lævo-form may be the one found in nature, but never both and never the racemic compound. Glycine forms mono-clinic crystals which are freely soluble in water, but insoluble in alcohol and ether. When the ethyl ester of glycine is allowed to stand in aqueous solution two molecules of alcohol split off and glycine anhydride



results. This is the simplest of the 2 : 5 di-keto-piperazines. It is of great interest because when hydrolyzed instead of taking up two molecules of water and going back to glycine, it takes up only one molecule, breaking the ring between the amino and the carbonyl and forming the simplest dipeptide, glycyl-glycine

[3] Holleman second edition, p. 247, 1907.
[4] Curtius, Journal für praktische Chemie, vol. 37, p. 150, 1888.

$NH_2CH_2CONHCH_2CO_2H$. In *alanine*, alpha-amino-propionic acid $CH_3\dot{C}HNH_2CO_2H$, the asymmetric carbon atom which characterizes all these compounds except glycine has already appeared. It is marked with a star in the formula. Only the dextro-isomer is found in nature. Synthesis from α-halogen propionic acid and ammonia leads, of course, to the racemic compound. The two isomers can be separated by first benzoylating the amino group and then making the brucine salt. The salt containing the lævo-isomer crystallizes while that of the dextro-compound stays in the mother liquor. The free amino-acids are then regenerated by the usual methods.

The passage from dextro-alanine to lævo-alanine and back again over what Fischer has called the "Walden reversal" is interesting. When l-α-amino-propionic acid is treated with nitrosyl bromide the amino group is replaced by bromine but only d-α-brom-propionic acid is produced—there is a change in the configuration. This when treated with ammonia yields d-α-amino-propionic acid (d-alanine). Thus we have passed from the lævo- to the dextro-compound without racemization. In order to pass back again to the lævo-compound we have only to treat the d-alanine with NO Br when it gives only l-α-brom-propionic acid, which on treatment with ammonia yields l-α-amino-propionic acid (l-alanine) again.

l-α-amino-propionic acid $\leftarrow NH_2\leftarrow$ l-brom-propionic acid (l-alanine).

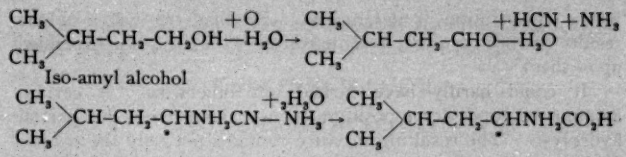
$$\downarrow \quad\quad\quad\quad \uparrow$$
$$NO\ Br \quad\quad\quad\quad NO\ Br$$
$$\downarrow \quad\quad\quad\quad \uparrow$$

d-brom-propionic acid $\rightarrow NH_2\rightarrow$ d-α-amino-propionic acid (d-alanine).

L-leucine, α-amino-isobutyl-acetic acid

$$\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>\!CH{-}CH_2CH\ (NH_2)\ CO_2H.$$

is particularly abundant as a constituent of the protein molecules. It has been synthesized from iso-amyl alcohol over iso-valeraldehyde and the cyanhydrin synthesis. Naturally this yields d-l-leucine but it can be split up by making the formyl compound and then the brucine salt.



In addition to these simple compounds we meet among the decomposition products of protein with amino-oxy-acids like serine $CH_2(OH)CH(NH_2)CO_2H$, with amino-di-carboxylic acids like aspartic acid $CO_2HCH(NH_2)CO_2H$ and with di-amino-acids. Some of the most important of the amino-acids, like tyrosine, proline, and tryptophane contain aromatic or heterocyclic nuclei.

4. THE SYNTHETIC METHOD.

Total hydrolysis, then, has given us, in connection with the ester method, what appears to be a fairly complete account of the simpler constituents of the protein molecules. So far, eighteen amino-acids have been identified with certainty among the decomposition products. But it leaves us without information upon the question of how these constituents are united. The obvious way of attacking this problem is to apply gentler methods of hydrolytic decomposition and endeavor to get hold of intermediate compounds between the protein and the amino-acids. As a suitable method, standing in the cold with acid for varying lengths of time has been tried. Still more promising was the decomposition of proteins by means of ferments analogous to those active in the various digestive processes.

An enormous amount of work has been done along this line and from the products of fermentative and chemical partial hydrolysis of protein a large number of substances has been separated and described. In no case, however, has any satisfactory evidence been furnished that the material obtained was a pure chemical substance and, in most cases, the materials separated have not been investigated with a view to ascertaining the amino-acids of which they were made up. It is clear that no knowledge is obtained regarding the make up of the original substance unless the intermediate product is a pure compound

whose constitution is determined. So that the value of the results has been scarcely commensurate with the labor expended upon them.

It could hardly have turned out otherwise. A certain amount of total decomposition occurs along with the partial hydrolysis. The resulting mixture contains not only the amino-acids—whose separation, as we have seen, defied chemists until the invention of the ester method—but, along with them, a large number of intermediate products, more complicated in character and less inclined to crystallization. The researches of Kühne, Hofmeister, Neumeister and other physiologists have shown how, chiefly by precipitation-reactions, this mixture can be separated into various fractions and that, if one rigidly adheres to the same conditions, the corresponding fractions obtained in different experiments will behave in about the same way. But this is no proof that they are pure substances. *"Die verschiedenen Sorten von Albumosen und Peptonen mit denen die Physiologen rechnen, für den Chemiker nur unentwirrbare Gemische bedeuten können."* [5]

Here, then, the chemistry of albumin threatened to come to a standstill, for the separation of the mixture under discussion has not been carried out and will not be until more effective methods than those we possess at present are devised. It was at this stage that Emil Fischer made his daring and successful attempt to travel the synthetic road. Starting with the idea that the amino-acids in the proteins are connected by an amide linkage, he undertook to build up from the various amino-acids pure compounds of perfectly definite composition and properties and then to search for them in the decomposition products of the proteins. So far, he and his co-workers have prepared more than a hundred of these compounds. He calls them *polypeptides*. A compound composed of two molecules of amino-acid is a dipeptide, one composed of three a tripeptide and so on. This nomenclature holds whether the molecules linked are alike or not.

The simplest polypeptide is *glycyl-glycine*—two molecules

[5] Fischer, Untersuchungen über Aminosäuren, Polypeptide und Proteine. 1906. Berichte der Deutschen Chemischen Gesellschaft, vol. 39, p. 530, 1906.

of glycine linked. It may be conceived as resulting with loss of water, though this is not the actual method of making it.

$$NH_2CH_2COOH + H_2NCH_2COOH =$$

$$NH_2CH_2CONHCH_2CO_2H + H_2O$$

Glycyl-glycine is, of course, a dipeptide. Using Fischer's general synthetic methods which we shall glance at in a moment we can introduce into its amino group another glycine residue, obtaining di-glycyl-glycine—

$$NH_2CH_2CONHCH_2CONHCH_2CO_2H$$

This is the simplest tripeptide. There is no definite limit to this process of building up. But, instead of restricting ourselves to glycine, there is nothing to prevent our using any one of the other amino-acids at any stage. For instance l-leucine can be coupled with glycine obtaining *l-leucyl-glycine*

$$\begin{matrix} CH_3 \\ \\ CH_3 \end{matrix}\!\!\diagup\!\!\diagdown CH—CH_2\overset{*}{C}H(NH)_2CONHCH_2CO_2H.$$

Or glycyl can be introduced into l-leucine, producing *glycyl l-leucine*

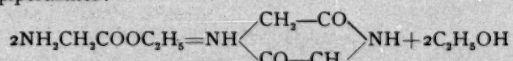
$$NH_2CH_2CONH\overset{*}{C}H(C_4H_9)CO_2H.$$

As a matter of fact both these compounds have been prepared and, although so similarly made up, the structural difference occasions a total difference in properties.

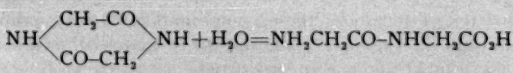
When one considers the infinite possibilities of permutation and combination among the eighteen amino-acids known, one must admit that—while there is no evidence that this amide linkage is the only scheme according to which the protein molecule is constructed—it alone is sufficient to account for the immense variety of natural proteins. Except the vast difficulty and labor of such a synthesis, there is no *a priori* reason why the whole eighteen amino-acids known should not be built up into a single molecule. In fact, Fischer has made an octa-decapeptide containing eighteen amino-acid residues, though they were not all different. It will be noted also that all the polypeptides, except those composed of glycyl residues alone, contain

asymmetric carbon atoms (starred in the formulas). This multiplies the staggering number of structural isomers by 2^n where n is the number of amino-acid residues (other than glycyl) in the molecule. Restricting the discussion to synthesis, these isomers would be grouped in enantiomorphous pairs and the members of each pair would unite to form a racemic compound which would again be different from the enantiomorphs. However, in the case of the amino-acids, it appears that only one of each pair of enantiomorphs can occur in nature. If this turns out to be universally true, geometrical isomerism would have no application to the natural proteins except to explain their optical activity.

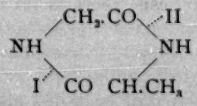
We must now consider, very briefly, the actual methods by which Fischer and his co-workers have effected the synthesis of the polypeptides. The oldest of these methods, historically, we have already noticed. The esters of the α-amino-acids have a tendency to split off two molecules of alcohol and go into 2 : 5 di-keto-piperazines:—



This compound when treated with hydrochloric acid, or better with dilute caustic potash, takes up one molecule of water yielding glycyl-glycine



This method has received only a limited application. It is plain that it can yield only dipeptides. The higher amino-acids do not so easily go over into di-keto-piperazines, and difficulties arise in the hydrolysis of the latter. A further complication arises from the presence of two amino-acid residues in the ring of a mixed di-keto-piperazine [6]—*e.g.*, Glycyl-alanine anhydride



[6] Aberhalden "Eiweisschemie," p. 84.

If, in the hydrolysis, the ring is broken at I, glycyl-alanine,

$$NH_2CH_2CO.NHCH(CH_3)CO_2H,$$

is the product. But if the rupture occurs at II, alanyl-glycine

$$NH_2CH(CH_3)CO.NHCH_2CO_2H,$$

results. The separation of these two dipeptides—both of which do, as a matter of fact, result from the hydrolysis of glycyl-alanine anhydride—is quite difficult. Added to all this is the fact that, in the hydrolysis of optically active di-keto-piperazines, the danger of racemization must be constantly borne in mind.

Another method which has played only a small rôle in the development of the subject is the synthesis of polypeptides by means of the ester of lower polypeptides. Thus, when the methyl ester of di-glycyl-glycine is gently heated, methyl alcohol separates and the methyl ester of penta-glycyl-glycine is formed which, on saponification, yields the hexapeptide itself:

$$2NH_2.CH_2CO.NH.CH_2CO.NH.CH_2CO_2CH_3=$$

$$CH_3OH+NH_2CH_2CO.(NHCH_2CO)_4.NH.CH_2CO_2CH_3$$

The most productive method has been the application of halogen-acyl-compounds. To take the simplest example: when glycine is treated with chlor-acetyl-chloride, the amino group reacts with the chlorine combined with carbonyl in the usual way, producing chlor-acetyl-glycine. By treatment with ammonia the chlorine atom is then exchanged for an amino-group, yielding glycyl-glycine. Thus:

$$Cl.CH_2COCl+NH_2CH_2CO_2H=$$

$$Cl.CH_2.CO—NH.CH_2CO_2H+HCl$$

$$Cl.CH_2CO—NH.CH_2CO_2H+2NH_3=$$

$$NH_2.CH_2.CO—NH.CH_2.CO_2H+NH_4Cl.$$

The great possibilities of this method will be evident. Any amino-acid can be used instead of glycine. Glycyl-glycine and

the other dipeptides can be employed instead of the amino-acids. This gives use to the tripeptides:

$$Cl.CH_2.COCl + NH_2.CH_2.CO—NH.CH_2.CO_2H =$$
$$Cl.CH_2.CO—NH.CH_2.CO—NH.CH_2CO_2H + HCl$$

$$Cl.CH_2CO—NH.CH_2CO—NHCH_2CO_2H + 2NH_3 =$$
$$NH_2.CH_2.CO—NH.CH_2CO—NH.CH_2.CO_2H + NH_4Cl.$$

The tripeptides can be built up in turn into tetrapeptides and so on.

On the other hand, other halogen-acyl-chlorides can be used instead of chlor-acetyl-chloride. Thus, if it is desired to introduce alanyl, α-brom-propionyl bromide is used and the synthesis carried out in the same way.

As will be seen, the possibilities of the method are sufficiently extensive. An obvious limitation is the fact that it is impossible to build up the molecule beyond the carboxyl. All the constructive work is done at the other end. This restriction has been removed by the discovery that by special methods, which space forbids us to discuss, it has been found possible to replace the carboxyl hydroxyl in the amino-acids and even in the polypeptides by chlorine. The resulting compound is an acid chloride and can be handled exactly like one in the synthesis just outlined.[7, 8, 9]

The fact that all the proteins and their decomposition products are optically active indicates that the complications which result from the presence of asymmetric carbon atoms in the materials employed for these syntheses cannot be ignored. In fact their experimental elucidation constitutes one of the main objects of research. The main stress must be laid on the synthesis of optically active products, for these alone are met with in nature.

So far as the introduction of glycyl is concerned the matter is simple. Chlor-acetyl chloride contains no asymmetric carbon and its introduction into an active amino-acid can give only one optically active product. The other α-halogen acid chlorides do

[7] Berichte der Deutschen Chem. Gesellsch., vol. 37, p. 3070, 1904.
[8] Berichte der Deutschen Chem. Gesellsch., vol. 38, p. 610, 1905.
[9] Berichte der Deutschen Chem. Gesellsch., vol. 38, p. 2914, 1905.

contain asymmetric carbon and of course the racemic compound is the only one obtainable by direct halogenation of the acid. When this substance is used with the active amino-acid in the reaction under discussion two stereo-isomeric but not enantiomorphous dipeptides will result. The mixture of these will be active whether the isomers are produced in equal quantities or not. In most cases the solubilities of the two substances are so similar that their separation is impossible.

Another way of handling the situation would be to separate the racemic halogen acid chloride into its enantiomorphs beforehand, but the immediate reaction of the acid chlorides with water forbids the application of any of the usual methods.

A more promising possibility is the separation of the enantiomorphous halogen-acyl-amino-acids by brucine or some other active alkaloid before treatment with ammonia; but, so far, the experimental difficulties have proved insurmountable.

So that we are driven to start the synthesis with an active halogen acid chloride. Unfortunately these substances are difficultly accessible. One of the most promising means of preparing them is by means of the "Walden reversal" briefly sketched above.[10] Suppose the dipeptide we desire to make is d-alanyl-d-alanine,

$$CH_3.CH.(NH_2).CONH.CH(CH_3)CO_2H.$$

The raw materials are d-alanine and l-alanine both of which are obtained without difficulty. d-alanine is ready for the synthesis without further treatment. The l-alanine, when treated with nitric oxide and bromine yields by the "Walden reversal" d-α-brom-propionic acid, which can easily be converted into its chloride. By coupling this with the d-alanine we obtain d-brom-propionyl-d-alanine, which on treatment with ammonia gives d-alanyl-d-alanine.

Finally, there remains the possibility of simply converting an active amino-acid into its chloride and then coupling with another active amino-acid, thus avoiding the use of the halogen acid chloride altogether. Very little has yet been done along this line. The method is very promising. Since, as briefly indicated above, it applies not only to amino-acids but also to poly-

[10] Aberhalden, Eiweisschemie, p. 85, 1909.

peptides, it will probably play an important rôle in the further development of the subject.

5. THE POLYPEPTIDES.

As already noted, more than a hundred polypeptides have been built up by the methods at which we have just glanced. Most of them, with some important exceptions, are soluble in water, and more readily in solutions of acids and alkalies on account of salt-formation. They are insoluble in ether and alcohol, although the latter, with the addition of a little aqueous ammonia is a good solvent for them. When the ammonia is driven out by heat the polypeptide precipitates.

From the tripeptides upward, they yield the biuret reaction, which is regarded as characteristic of the peptones.

Their behavior toward the digestive ferments is most interesting. So far no hydrolytic action of the gastric juice has been detected, but only a few experiments have been made and positive results, especially with the higher polypeptides, will probably be obtained by further work. On the other hand, an elaborate research[11] shows that the pancreatic secretion digests many of them. The attack depends upon the nature of the amino-acids, the length of the chain, and especially upon the spatial configuration. An extraordinary instance of the fineness with which the ferments are adjusted to their special functions is found in the fact that *only polypeptides formed of the active amino-acids which occur in nature are hydrolyzed.* Fischer suggests that the continuation of these researches upon the action of pepsin and pancreatin upon the higher polypeptides may result in drawing a sharp boundary between stomach and intestinal digestion.

It is equally impossible and undesirable to catalogue here the hundred or more polypeptides which have thus far been obtained. We shall merely glance rapidly at the simplest and at the most complicated. The others can be sought for by those specially interested in the original papers.[12]

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[11] Fischer and Aberhalden, Zeitschrift für Physiolog. Chemie, vol. 46, p. 52, 1905.

[12] Fischer's Untersuchungen über Aminosäuren, Polypeptide und Proteine (1906), is a collection of his papers, reprinted with an index and the résumé delivered before the German Society in 1906 as an introduction.

As already noted, the simplest polypeptide is glycyl-glycine:

$$NH_2.CH_2.CO.NH.CH_2CO_2H.$$

We have already noted the methods by which it is obtained. It crystallizes in leaflets which have a pearly lustre. It melts above 200° with simultaneous decomposition. The last sentence might almost be written of the polypeptides in general. Various derivatives have been made.

Glycyl-glycine will always remain the simplest polypeptide, but the most complicated is clearly a function of the state of research at the time. At present the position is occupied by an octa-deca-peptide, i.e., a substance containing eighteen amino-acid residues united by an amido linkage. This substance is l-leucyl-tri-glycyl-l-leucyl-tri-glycyl-l-leucyl-octa-glycyl-glycin.

$$NH_2.CH(C_4H_9).CO.(NHCH_2CO)_3.NHCH(C_4H_9)CO.$$

$$(NHCH_2CO)_3.NHCH(C_4H_9)CO.$$

$$(NHCH_2CO)_8NHCH_2CO_2H$$

This polypeptide dissolves only partially in 100 parts of boiling water. The solution foams even when very dilute. It is precipitated by ammonium sulphate, but not by mercuric chloride nor by an acid solution of mercurous nitrate. The molecular weight of the substance is 1213.3. It is the most complex compound yet synthetized by methods which have, at every step, kept clear the constitution of the product.

6. STRUCTURAL POSSIBILITIES OF THE POLYPETIDES. CONFIGURATION.

The syntheses and reactions of the polypeptides leave no doubt that in them the amino-acids are coupled by an amide linkage. This, however, is far from settling their structure. It simply means that in them we meet, in a more complex form, with all the unsettled questions regarding the structure of the amino-acids themselves.[13] That is, we must reckon with the possibility of lactam and lactim forms on the one hand and on the other with the question whether we have to deal with a free

[13] Fischer, Lecture before the German Chem. Soc., Jan. 6, 1906. Berichte, vol. 39, p. 530.

amino-acid or with an intramolecular salt. This gives for glycyl-glycin the following four possibilities:

$$NH_2CH_2CONHCH_2CO_2H \quad (1)$$

$$NH_3CH_2CONHCH_2COO \quad (2)$$

$$NH_2CH_2C(OH):NCH_2CO_2H \quad (3)$$

$$NH_3CH_2C(OH):NCH_2COO \quad (4)$$

One of these possibilities—the antithesis between free acid and intramolecular ammonium salt—will clearly be unaffected by the length of the polypeptide chain. So far as the number of isomers due to this cause is concerned it will remain the same in the higher polypeptides unless poly-carboxylic- or poly-amino-acids enter the molecule. In this case further complications arise, which we have not space to discuss, especially as experimental research has not gone far enough to afford any evidence to test the theoretical conclusions.

The other possibility—that of the lactam or lactim form—is a function of the number of amide linkages, and the number of isomers due to it increases with the length of the chain.

The decision which of the four possibilities above outlined best represents the behavior of the polypeptides must be left to the future. All that can be said at present is that there are fairly clear indications of the existence of more isomerides than can be accounted for by the open chain formula without double linkages. Thus, leucyl di-glycyl-glycine is obtained as an amorphous substance, freely soluble in alcohol. When the alcoholic solution is warmed, the tetrapeptide separates in a crystalline modification, almost insoluble in alcohol.

The consequences which result from the application of the theory of the asymmetric carbon atom to the polypeptides have already been briefly discussed. Lack of space and lack of substantial experimental basis alike forbid us to lose ourselves in tracing out the fascinating possibilities which arise. One or two almost self-evident results which happen to be useful in explaining the results of experiment may be mentioned.

When inactive halogen acid chloride and inactive amino-acid are allowed to interact four kinds of molecules are present.

Representing the acid by the subscript A and the chloride by C we have

$$d_A,\ l_A,\ d_C,\ l_C.$$

So that there are four possibilities for the configuration of the resulting dipeptide

$$(1)\ [d_A\ d_C],\ (2)\ [d_A\ l_C],\ (3)\ [d_C\ l_A],\ (4)\ [l_A\ l_C].$$

Of these (1) and (4) are mirror images and must therefore be produced by the reaction in precisely equal quantities. The same is true of (2) and (3). (1) will unite with its enantiomorph (4) to form the racemic compound

$$[(d_A\ d_C)\ (l_A\ l_C)]$$

while (2) with its enantiomorph (3) will yield

$$[(d_A\ l_C)\ (d_C\ l_A)]$$

The theory predicts nothing regarding the relative quantities in which these two racemic compounds will be formed except that they will not, in general, be the same. The very great and even dominant influence of configuration on the velocity of chemical changes has been established in countless cases, and it is possible for one of the compounds to be so far preferred that the amount of the other formed is negligible. In that case it is somewhat difficult to place its character as a pure substance beyond doubt. Or, it may be that both racemic compounds are produced in appreciable quantities. Then the chemist must face the problem first of separating them and afterward of determining which is which. This is not so simple as might appear. Thus in the synthesis of dl-alanine-dl-leucine, the following four active forms and two racemic compounds are possible:

$$\underbrace{\text{d Alanyl-l-leucine}\quad \text{l-Alanyl-d-leucine}}_{\text{Racemic Compound } A}$$

$$\underbrace{\text{d Alanyl-d-leucine}\quad \text{l-Alanyl l-leucine}}_{\text{Racemic Compound } B}$$

The synthesis and the properties of the two compounds threw no light upon the question which was *A* and which was *B*. In order to decide the point it was necessary to resort to the action

of pancreatic secretion. The racemic compound *B* resisted the secretion completely and could be recovered unaltered. During the experiment the solution remained optically inactive.

A behaved under the same experimental conditions in an entirely different manner. It was hydrolyzed and the solution became active, showing that the hydrolysis was occurring asymmetrically. Now it has been abundantly demonstrated that only linkages between amino-acids which occur in nature are broken by pancreatic secretion. Since only d-alanine and l-leucine occur in the natural proteins, d-alanyl-d-leucine, l-alanyl-l-leucine and l-alanyl-d-leucine would all be unaffected. Only d-alanyl-l-leucine would be hydrolyzed. Thus the compound which is digested must have the configuration *A*. The fact that l-analyl-d-leucine was not affected and accumulated in the liquid explains why the solution became optically active.[14]

7. PROOFS THAT THE AMIDE LINKAGE OCCURS IN THE PROTEINS.

What is the evidence that the amino-acids are to be regarded as constituents of the protein molecule? May not the unstable molecule undergo complicated rearrangements during the breaking-down? Have we any right to regard the amino-acids as existing preformed in the proteins? These questions must be candidly faced, for, if they cannot be answered, the polypeptides become merely a remarkable group of synthetic products and the peculiar interest attaching to them is lost.

Briefly, the evidence is this. The three different methods of hydrolysis, by acids, alkalies and ferments, when applied to the same protein, give identical results. The same amino-acids are formed in—so far as the ester-method informs us—the same quantity. This is unthinkable if complicated molecular readjustments be imagined to precede the formation of the amino-acids, for then the results would differ according to the method of attack. Special weight must be attached to the fact that digestion of the proteins with trypsin at blood-heat gives the same final results as hydrolysis with boiling acids and bases, for in this gentle method of attack there is not the least reason for assuming secondary transformations.

[14] Fischer and Abderhalden, Zeitschr. für physiologische Chemie, vol. 46, p. 52.

Admitting that the amino-acids are to be regarded as preformed in the proteins, what is the evidence that they are linked in the same manner as in the artificial polypeptides? We have remarked that ferments are extraordinarily specific in their action and that slight differences of configuration suffice to prevent the attack. The fact that polypeptides are hydrolyzed to amino-acids by the same ferments which produce the same effect on the proteins is a convincing proof of the close kinship of the two classes of substances.

When a dog is fed with polypeptides, or when they are given subcutaneously, the same products are obtained as upon administration of albumin.

Finally, polypeptides have been found among the products of the partial hydrolysis of the proteins in a number of cases. Thus the proof that in albumin the amino-acids are coupled by an amide linkage is complete. While this is certainly the chief mode of connection there is no evidence that it is the only one. Fischer believes that the proteins contain piperazine rings. It is not probable that the hydroxyl groups of the oxy-amino-acids are indifferent. They may combine with each other with elimination of water after the manner of an ether; they may be estrified by the carboxyl groups in the same molecule and so on. Since the lack of experimental evidence is almost complete, speculations of this sort are unprofitable at present. But it is clear that the theory will be able to explain without difficulty the great number of the natural proteins and their delicate gradations of behavior.

8. CONCLUSION.

The way is now open for the successful attack of those complex mixtures which the physiologists refer to as albumoses, proteoses, peptones and so on. We have seen that there is no reason to believe that a single one of these materials is really a chemical individual. They will now be worked up by the chemist in the effort to prepare pure substances from them. The knowledge now at hand of the properties of the polypeptides which we may expect to find in these mixtures will be of great assistance. Then the compounds obtained will be compared with the synthetic products and identified. The result will be to clear up the nature of the digestive processes on the one hand and the structure of the original protein on the other.

So that, while the proteins have not been made artificially, their riddle is to all interests and purposes solved. We know their constituents and are fairly sure of the mode of connection, and great progress both in chemistry and biology may be confidently anticipated from the knowledge. Not all of this great result is due to Emil Fischer. Curtius and Kossel have made contributions of the utmost importance, and, among Fischer's co-workers, Emil Aberhalden's name will be associated with that of the master. But the polypeptide syntheses proper are Fischer's own. The highest praise we can give the work is to say that it is worthy to be placed beside his researches on the sugars and those on the purine nucleus. Taken together, the three give him an unquestionable right to be regarded as the first synthetic organic chemist of the present time.

ELECTRIC FURNACES IN GERMANY.

Hitherto electric furnaces in Germany have been used chiefly for the treatment of small quantities, but now the leading works are beginning to employ them on an extensive scale for handling large quantities of metal. At the close of 1907 one of the most important steel works in the Empire engaged in the production of cast steel for gears, as well as of the softer varieties of malleable cast steel for automobile construction and for minor machine parts, decided to replace its battery of crucible furnaces by a large electric fusion furnace. The main cause for the change was the desire to materially lessen the cost of fusion, while not lowering the quality of the steel, but, on the contrary, improving it, if possible.

The old equipment consisted of 32 furnaces, each containing 6 crucibles with a capacity of 77 pounds. They are replaced by a single electric furnace of 250 horsepower, capable of holding a charge of a metric ton (2,205 pounds). A duplicate furnace is likewise installed and kept as a reserve for emergencies.

Electricity is supplied from the large works of a company near Cologne, which furnishes a three-phase current of 5,200 volts to quite a large territory near the Rhine for both power and illumination. Alterations in the current intensity are so slight that connection is made directly, without the interposition of a regulator, between the furnace and the transforming station. At the latter a three-phase rotatory current, reduced to a tension of 110 volts, is supplied.

PRODUCTION OF CAST STEEL.

The production of cast steel in this furnace has been carried on since the beginning of 1908 without interruption, and with such a degree of success that the results are well worthy the attention of American steel manufacturers. Details of the cost and process generally are herewith reproduced in some fulness, on account of the far-reaching importance of this revolution in the central feature of one of the leading industries of the United States.

The main product of the furnace has been cast steel, containing about .06 per cent. phosphorus, .03 per cent. sulphur, and from .08 to .18 per cent. carbon. Occasionally charges of tool steel have been cast, containing from .7 to 1.3 per cent. of carbon, with and without the addition of nickel, chromium, or tungsten. The material employed is ordinarily slugs, cuttings, turnings, and other waste of wrought iron, costing from $14.28 to $15.47 per metric ton

(2,205 pounds) $12.96 to $14.04 per short ton. A fusion, including the refining, lasts about five hours and involves a consumption of about 900 kilowatt hours for 1 metric ton of cast steel. The entire charge of one ton is poured at once. When the furnace is kept in continual use the magnesite lining lasts for about 70 operations, *i. e.*, twenty to twenty-five days. A stoppage of five days is required for each renewal, but during this period the reserve furnace is employed.

The cost of the electric current is exceedingly low, on account of the large amounts consumed. It amounts to 4½ pfennigs (1.071 cents) per kilowatt hour, so that the expense for a single operation is about 40 marks or $8.64 per short ton.

The total cost of cast steel, thus produced, per metric ton, is as follows:

For—	Cost.
Amortization of cost of plant	$1.19
Raw materials, including additions, chromium, etc.	16.66
Electric current, including heating during intervals	10.71
Renewal of magnesite lining	2.85
Labor	2.38
Electrodes	.60
Water for cooling purposes	.12
Total	34.51

This amounts to $31.32 per short ton, and is materially less than the cost of crucible steel.

ADVANTAGES OF THE ELECTRIC PROCESS.

The manufacturing firm notes in addition these advantages in the electric process, as compared with the old method: (1) Cheaper raw material can be employed in the place of the more expensive Swedish iron formerly required; (2) in fusing quantities of a ton at a time it is possible to produce homogeneous masses of a distinct, well-defined grade; (3) the molten steel leaves the furnace at a much higher temperature than when prepared in crucibles, is therefore in a more liquid condition, and is easily transferred to ordinary ladles, preparatory to pouring into the molds of small castings.

These electric furnaces are arranged on the Stassano system, and are supplied in all sizes, for charges varying from 400 pounds to 10 tons, and are adapted for the fusion of metals of every kind.

The furnace for cast steel is constructed of iron plates, heavily lined with magnesite bricks. Carbon electrodes enter by three openings on the sides, and are so adjusted as to terminate slightly above the surface of the molten metal, whereby the heat of the arc is absorbed almost entirely by the contents of the furnace, and but a small portion is radiated upward to be reflected from the concave dome.

MIXING AND FUSION—OTHER USES.

A thorough mixing of the component parts of a charge is effected by mounting the furnace on an axis, slightly inclined from the vertical. A steady revolution about this axis is maintained through a cogged connection, with a dynamo of 5 horsepower, the edge of the furnace resting on ball bearings. This rotation causes the lower layers to gradually rise to the top of the molten mass, and brings about a thoroughly uniform mixing. The electrode supports are inclosed in cylinders and surrounded by a current of cold water. These supports are in rigid connection with hydraulic cylinders, by means of which the movements of the electrodes are under perfect control.

A fusion requires 3½ hours to be complete; a further period of 1½ hours is requisite for the removal in succession of phosphorus and sulphur, and the final deoxidation of the contents of the furnace. No interruption

occurs in either the current of electricity, or in the supply of water for cooling the electrode supports, while the furnace is in rotation. Special devices have been provided for both purposes.

The services of three workmen are required to conduct an electrical furnace, change electrodes, transport the raw materials, etc. Furnaces of the type in question are now being introduced in Germany for the treatment of other metals and alloys, and it is apparently only a question of time before the crucible processes hitherto in such general use will be completely superseded.—*Consular Report.*

GOVERNMENT STUDIES NAVAL STORES INDUSTRY.

THE United States Government has for the past five months been making investigations of the timber supply as it is related to the naval stores industry of the Southern States. A special appropriation was made by the last Congress to carry on this work. For some time those interested in the turpentine industry have felt the need of accurate data regarding the supply of timber still available for the production of turpentine. The degree of injury sustained by the long-leaf pine during the process of bleeding for resin has always been a subject of contention between the lumbermen on the one hand and the turpentine operators on the other, and a special effort was made to ascertain reliable facts bearing upon this phase of the investigation. Statistics of production are also in process of compilation. The present methods of obtaining resin from the tree and especially the extent of use and the practicability of the new cup system of collecting gum have come under careful study. In order that the best possible results might be obtained all parts of the naval stores producing region were visited; the best informed operators were interviewed and observations were made in regions of varying conditions. The data collected in the turpentine investigation are now being brought together, in a report which will later be published. Some of the points brought out are as follows:

The new cup systems of gathering the gum, whereby the injurious hole or "box" cut in the tree to catch the gum has been replaced by a cup hung on the tree, have generally proved both practical and profitable, and are everywhere gaining in favor.

As compared with the old and exceedingly injurious "box" system these new methods unquestionably lessen the injury done to the timber and lengthen the average life of the tree after bleeding. This increase in efficiency is due to the fact that the cup systems render the tree less susceptible to damage by subsequent fires.

The United States Forest Service men who made the investigation found the field of the turpentine operator is moving westward. As the available timber in the older sections of the Eastern States becomes exhausted the operator moves farther west in search of new fields.

Finally, the available supply of turpentine timber in the United States is likely to be exhausted within the next fifteen years to the extent that the turpentine industry as related to the production from living trees will be seriously curtailed, while a large falling off of production will probably occur within ten years. This condition will be a surprise to many who have held that large areas of fine pine timber in the states of Mississippi, Louisiana, and Texas will come under production and thus tend to offset the falling off in the East. It has been found, however, that the conditions differ in these states as the timberlands are held in bodies of considerable extent by large companies who will not allow their timber to be bled. Their experience in turpentining leads them to the view that the damage done to the timber more than offsets the additional revenue and has caused them to become antagonistic to any advance looking toward the tapping of their timber. For this reason the naval stores industry will probably never become the factor in these states that it has on the Atlantic Coast.

INCREASE IN USE OF WOOD PRESERVATIVES INDICATES PROGRESS IN FOREST CONSERVATION.

AN increase from three and one-half million gallons of the oil of coal tar, or creosote, as it is popularly known, imported into the City of New York in 1904, to an amount estimated to be almost twenty-five million gallons last year, is one of the indications pointing to the progress of the nation-wide movement for the conservation of forest resources.

It is creosote which the government and scores of corporations and private wood users have found to be one of the most satisfactory preservatives of railroad ties, mine props, telephone and telegraph poles, fence posts, and for timbers used for other commercial purposes. Lengthening the life of timber in use means the lessening of the drain on the country's forests, and what is more important to the average business man, it means the saving of thousands of dollars annually spent for the labor of the frequent renewals made necessary when untreated timber is used.

Ten years ago the strongest advocates of the creosoting method of preserving wood could scarcely have hoped for the present advanced state of this industry. Creosoting is becoming the acknowledged standard means of increasing the life of timbers.

Formerly the production of creosote, from both coal tar and wood tar, far exceeded any demand for wood treating purposes. However, the number of wood-preserving plants has grown so rapidly within the last four years that this country is not now able to supply its own demand for coal tar creosote.

A brief study of the importation columns of the trade journals shows the effect of the growth of the wood preservation industry. In the whole year of 1904 the New York imports amounted to only 3,500,000 gallons. By the end of 1907, the importation had increased to 17,500,000 gallons, while for the present year conservative estimates place the imported coal tar creosote at between 22 to 25 million gallons.

The year has started most auspiciously; during a five-weeks' period in December and January the importation through New York alone was 15,000 tons, giving a weekly average of 3,000 tons or 68,000 gallons. It is significant that during this same period the importation of related by-products from coal kept pace with that of creosote. Ammonium carbonate, chloride, sulphate, and "sal ammoniac" entered to the amount of 104, 227, 1260, and 400 tons, respectively. If these had been all made into the sulphate, the equivalent product would have been 460 tons per week. The estimated ratio of twenty pounds of sulphate to one and one-half gallons of the creosote oil would make an equivalent production of 69,000 gallons of creosote. This is not far different from the 68,000 gallons which were really imported. Since these ammonia products and creosote are being imported in this relation, it is plainly evident that the production of creosote is not alone deficient, but also coal tar products in general.

The production of creosote in this country will, in all probability, continue to be far less than the consumption. The wood preservation industry has been in its infancy only, and enormous demands may be expected in the future. The coke, and consequently the coal tar industries, have until recently been at their best, but even at their best the supply of by-products has run short. On this account, we should turn to other sources to supply the increasing demands for creosote preservatives.

A great help may be eventually afforded by the increasing use of wood tar creosote which has not been in high favor in the past. It is gratifying to note that within the last few years some of the more important wood distillers have been turning into a profit those oils and tars which were formerly run to waste. The demand for these products is increasing, and this recovered by-product has been asserted to be not only a revenue for the producer but also a valuable preservative for the treatment of structural timber.

ORIGINAL COMMUNICATIONS

DEVELOP THE SUBMARINE!

BY

EDWIN SWIFT BALCH,

Member of the Institute.

It is an unfortunate fact that certain events of the last decade prove that it is still necessary for nations to be prepared for war. The founding of the International Court of Arbitration at the Hague in 1899 might have been expected to be the beginning of a peaceful era. It has not proved so as much as was hoped. Some troublesome incidents, such as that of the Dogger Bank, were settled by the Court at the Hague. But the Boer war, the Boxer troubles, the Russian aggressions in Manchuria, the German aggressions in Morocco and Kiau-Chau, the Russian-Japanese war, and the tearing up of Balkan treaties by Austria all show that wars may break out at any time, and that the nations of the world have not yet arrived at the stage of settling, as they should, all differences between nations by international law, diplomacy, and arbitration.

Reasoning from these same events, it is evident that nations must be ready, if the worst comes to the worst, to fight. China may be instanced as an example of this principle. Ten years ago, the European papers were talking constantly about the partitioning of China and about the respective European spheres of influence. Since the Japanese-Russian war, however,—that is, since the Europeans discovered that the yellow races could fight,—all that sort of discussion has ceased. The Europeans have stopped sowing the wind lest they should reap the whirlwind. Nevertheless it is only because it is felt that aggression might meet with a stern retribution, that the desire of partitioning the yellow man's goods has been so thoroughly quenched.

The outcome of the matter, as far as Americans are concerned, is to teach us that we must be prepared, under certain circumstances, to fight for our rights, or else possibly to be treated wrongfully by other nations. If such an unfortunate

event should occur, it would result in the nature of things that such a conflict would be mainly a maritime war, and it is therefore imperative for the United States to keep her navy ready for an emergency. What now is the naval problem before the United States?

The answer to this question would seem to be partly technical, partly political. It must be regarded, on the one hand, from the point of view of the man who handles the guns, that is, the naval officer; and on the other from the standpoint of the man who furnishes the guns, that is, the taxpayer.

To consider first the naval officer's view. Naval warfare to-day may be roughly divided into two classes: offensive warfare and defensive warfare. The consensus of opinion among naval strategists is that if war is to be made, the best thing to do is to take the offensive and hit the opponent hard: and the proper tool for this purpose is now usually claimed to be the all-big-gun battleship. It is, in fact, generally admitted by those who know best, that the heavy battleship is the only implement of real value in a naval engagement, and that armored cruisers, monitors, scouts, gunboats, destroyers and torpedo boats will count for but little in future contests.

Whilst there is doubtless truth in this belief, and that the best way to keep at peace may be to be prepared to strike vigorously, there is the other factor in the problem. This is the taxpayer. All these ugly battleships must be paid for at the rate of about ten million dollars apiece, with the certainty that in about twenty years time from their launching, these expensive masses of steel will have become obsolete and be *en route* for the scrap heap.

Is it entirely sensible for Americans to spend so much of our pocket money in preparations for offensive warfare? It is necessary to spend some. For several of the nations of the world,—Germany, England, France, Russia, Japan,—are at present engaged more or less—principally more—in a frantic race to see which country can first bankrupt its finances by building battleships. But as a nation, are we so anxious to enter on an offensive war? Offensive warfare is almost synonymous with a warfare of conquest or aggression. Benjamin Franklin said "there never was a good war, nor a bad peace." Let us stick to his philosophy.

The naval problem before the United States seems to be not

so much that of being prepared to engage in an offensive war of conquest, as to be ready, in case any foreign nation should want to attack us, to put up such a defence as to make it wish it had engaged in some other pastime. What this country needs is the householder's revolver against the burglar, not the magazine rifle of the road agent. In other words, from the business man's point of view, what the United States ought to do is to insure the safety of its coast by preparing for a defensive war.

Is the United States getting its naval defence revolver ready in the speediest and cheapest manner? An answer to this question is given incidentally to a certain extent in the recent book by Commander Murray F. Sueter, R.N., entitled: "The Evolution of the Submarine Boat, Mine, and Torpedo." It is a dispassionate and temperate presentation of facts and may well be recommended to the attention of the taxpayers, the Congress, and the Navy of the United States. The present article is in nowise a review of Commander Sueter's book. Any one interested in the subject can read that for himself. It is rather an attempt to draw conclusions from the facts presented by Commander Sueter, especially in regard to how those facts affect this country.

The United States is now building battleships equal to those of any other power. Is it doing as well in submarines? It is worth remembering, in this connection, that a good many mistakes have been made in ships for the present navy, and that much money has been wasted on ships which were practically obsolete when laid down. Some navy officers themselves admit that this was the case with the four monitors of the "Arkansas" class, the six cruisers of the "Denver" class, the three cruisers of the "Charleston" class, and the two battleships of the "Idaho" class. Possibly other mistakes may be made, which must be atoned for in hard cash.

Naval tactics to-day reduce themselves to two: smashing your adversary with a shell, or blowing him up with a torpedo. If you are going to use a big gun, you are forced to have a big ship on which to place it, and you are driven to the ten million dollar battleship. But if you are going to depend on the torpedo, the ideal implement from which to launch it seems to be the submarine. Submarines, in fact, have already developed to such a stage that they must be looked on as one of the main factors in future naval wars.

It seems as if it were hardly realized as yet what an unpleasant implement a hostile submarine is. The latest torpedos are effective up to 4000 yards, and at a distance where a submarine is dangerous, it is practically impossible for the best look-out men to detect, even in daylight, the little bit of an instrument, the head of the omniscope, which is all the submarine shows above water.

What submarines can do was shown during the Italian naval manœuvres in August, 1908. Four submarines, the "Glauco," "Narvalo," "Otaria," and "Squalo," unassisted, ran from Venice to Spezia, nearly 1300 nautical miles, without mishap. Of course, they could get supplies and fuel on the way. They then took part in the concluding operations between the combined fleets. One of the submarines, the "Glauco," in broad daylight, ran up to within striking distance of one of the battleships, the "Saint Ban," despite the vigilance of picket boats and the watch aboard the big ship, and torpedoed her twice, with collapsible head torpedos, before rising to the surface and revealing her position. In real war she would undoubtedly have sent ten millions of dollars of battleship to the bottom. The Italians have arrived at these results by unremitting experiments for several years with one submarine, the "Delfino," of which the other Italian submarines are only improved copies.[1]

Nevertheless, on account of the small radius of action possessed by submarines so far, they must for the present be looked on as chiefly important for defensive warfare, for the defence of coasts and harbors. For this purpose they seem by long odds the most dangerous weapon yet developed. Torpedo boats and destroyers are obsolete in comparison; for these cannot possibly attack in broad daylight; even at night, owing to sparks from the funnels and the bow wave when running at speed, they are liable to detection; and they are so delicate that one shell from a big rapid fire gun will probably put them out of commission. A submarine, on the other hand, is almost impossible to detect, and is protected against gunshot by the water above her. What the submarine may evolve into, as a weapon of offence, no one, of course, can foretell.

A fleet of submarines in sufficient numbers, owned by any country, would make it impossible for any fleet of hostile battle-

[1] Robert G. Skerrett: United States Naval Institute Proceedings, March, 1909, p. 328.

ships to come near that country's coast. No commander would venture to take the risk. In the case of the United States, a sufficiently numerous submarine fleet would free the battleship fleet from having to protect the coast, and this could therefore be used, if necessary, for offensive warfare. During the Spanish war, the United States fleet was hampered in its movements to some extent by the natural outcry from the coast cities for protection. This would happen again in any future war, unless it was known that there was some other means of protection.

Another fact of the greatest importance is the relative cheapness of submarines. Large ones can probably be built at present for less than one million dollars apiece; that is, ten of them could be built for less than the price of one battleship: and a hundred of them would practically guarantee the coast of the United States against aggression, which ten battleships would certainly not.

Let us consider for a moment what the two nations, France and Great Britain, who are most advanced in submarine navigation, are doing. They are experimenting steadily, which is synonymous with saying that both these nations are on the right track to improve their submarine fleet.

France began constructing submarines as far back as 1886. The first was of 30 tons. Only a few were built up to 1900. Many experiments were made, however, and two types developed. One kind, the *sousmarins,* are small, with little reserve buoyancy. The other, the *submersibles,* are big, with a good deal of reserve buoyancy. A number of both kinds have been built, some experts favoring one kind, others the other. Comparative trials, however, finally showed that the large *submersible* was superior to the *sousmarin,* for all practical sea-going work. In 1906, France built a number of *submersibles* of 398 tons, 167.72 feet long, with twin screws. She is now apparently building *submersibles* of 800 tons displacement, 227 feet long, surface speed 15 knots, submerged speed 10 knots, and radius of action 2500 miles without taking in fresh fuel. She has now about a hundred *sousmarins* and *submersibles* in commission and a large force of men thoroughly trained in their handling. The evolution of the submarine has proceeded apace among the French and it is questionable whether any hostile navy would dare to approach any part of the coast of France.

Great Britain started her submarine flotilla in 1901. She made a contract with the American Holland Boat Company, and this company built five submarines in England for the British government. After experimenting with these, Great Britain began building her own submarines, which are improvements on the original Holland type. In 1902–1904, she built thirteen of A type, in 1903–1905, eleven of B type, in 1905–1907, eighteen of C type, in 1906–1908, thirteen of D type. Each of these types embodies the improvements suggested by practical work with the preceding type. Type B, for instance, has a raised bow for surface running. Type C has two periscopes and twin screws. This type is 150 feet long, has a diameter of 13¼ feet, a displacement of 300 tons, speed on surface of 14 knots, speed submerged of 10 knots. Type D has larger displacement, better form for surface and submerged work, greater horse-power, more speed, certain improvements in the electric accumulator battery, and probably a more efficient torpedo armament. Great Britain, in fact, is evolving slowly, surely and steadily her submarine vessels, of which she has already a fleet numbering sixty. Despite all English talk and alarms, therefore, the British coast is one from which any hostile fleet would keep away.

Is the United States doing as well as France and England? Judging from Commander Sueter's statements, it is not. It may be our submarines are as good as any, but it is difficult to compare the submarines of various countries, because much secrecy is maintained in the matter. But apparently we are developing submarines, not by a gradual, logical, continuous process of evolution, but rather in a series of jumps, building a few now and then. Moreover, we have not half as many as we ought to have by this time. According to Mr. Robert G. Skerrett,[2] the United States have only nineteen submarines and one *submersible*, although eight more have recently been authorized. It may be suggested here incidentally that it would be a pity to adopt the French term *submersible*, because it is meaningless in English, and will also soon become corrupted into "sub-mur-sey-bel."

If Commander Sueter is correct, the United States is also not trying sufficiently every invention offered to it in connection

[2] United States Naval Institute Proceedings, March, 1909, p. 329.

with submarines. Commander Sueter states that about 1903, a submarine, the "Protector," was offered to the United States government. The Board of Officers who carried out experiments with her reported favorably: that she would be a valuable auxiliary to fixed mine defences, as a picket boat, to locate and pick up cables, as the best means of attacking mine fields. The Board recommended the purchase of five of these boats. Instead of doing this and proceeding to experiment with and develop this powerful weapon of defence, nothing was done. It is clear, however, that this was not the fault of the naval officers. The "Protector" was afterwards sold to Russia, which proceeded to do what the United States was too short-sighted to attempt.

Yet the "Protector" has several features which appeal strongly to an expert submarinist like Commander Sueter. One is a drop keel 5 tons in weight. Another is a diving compartment, through which the crew can escape if the submarine should go to the bottom and be unable to rise. A third is an even keel method of submergence instead of a dynamical dive. Commander Sueter says that he is certain that these features will be embodied by most nations in the construction of future boats, and at another place he says that the Japanese are building submarines which are a combination of the latest American types.

To the American citizen it makes no difference whatever what system of submarine is developed here. What he needs is protection, a suitable naval defence. And all the signs point to the fact that under present conditions the proper weapon with which to protect our coasts is the torpedo, launched from a submarine. The time may come when submarines will have to give way to some other implement: air ships perhaps. But that is another story.

What it would seem the United States ought to do, is to follow the lead of France and Great Britain and proceed to develop the submarine systematically. To do so, the government should try everything and encourage inventors. A few, perhaps four or five, submarines should be built each year. These should be placed in commission immediately on completion and experimented with continuously. Some improvements would pretty surely suggest themselves with each set to the officers in charge of them. These improvements should be embodied in the next set. We should develop, as the French have done, a

special corps of officers and men trained to submarine work. This corps should receive extra high pay, for working in a submarine, a steel tube filled with machinery, where one is semi-asphyxiated, is not agreeable, as anyone who will go aboard one for a short time will soon find out. It is impossible to foretell what a few years of steady experimenting would accomplish in the submarines themselves, but certain it is that the United States would thereby develop a powerful and relatively inexpensive weapon of defence.

ORES AND MINERALS OF THE SOUTHERN APPALACHIAN REGION.

REPORT BY THE GEOLOGICAL SURVEY.

THE present effort to establish a great national forest in the Appalachian Mountains has again drawn attention to the government report on the gold and tin deposits of the southern part of the region by L. C. Graton and Waldemar Lindgren, which was published by the United States Geological Survey as Bulletin 293.

Mining in this general region dates back to the beginning of the history of America, for the early Spanish and English records contain accounts of the discovery and recovery of metals. The principal mineral resource is gold. When the early Spanish explorers came to America, they were shown by the Indians rich nuggets and ornaments of gold from the southern Appalachian region, some of which is supposed to have come from the area covered by this report. The Spaniards mined gold in Georgia in the seventeenth century. From 1825 to the present time production has been continuous. Unfortunately, no reliable statistics of the production are to be had, but to judge from all available data it seems probable that the total value of the gold mined has been about $10,000,000. A considerable but unknown proportion of this amount has been derived from placer deposits, but much the larger part has been won by hard-rock mining. Iron has been mined in the southern Appalachians, and within recent years the monazite industry has attained some importance in the Carolinas. Copper, lead, manganese, pyrite, mica, barite, corundum, clay, limestone, and granite have also been found and worked. Besides these minerals tin ores occur in this region.

NEED OF FINDING TIN ORES.

The world's use of tin is steadily increasing and the demand for it is constantly growing. New deposits are discovered from time to time, and certain districts already known are increasing their output, but the production of some of the important tin-mining regions of the world is declining and that of others can not long be maintained. The reserve stocks held in various parts of the world are accordingly being greatly depleted and the price of tin is gradually becoming higher.

For these reasons the discovery of new deposits of tin ore is of great interest to mining men and to many who are connected with the metal industry, as well as to investors. The United States consumes over 40 per cent. of the world's output of tin, but contributes an inappreciable amount, so that any information regarding deposits of tin ore in this country is of especial interest. The southern Appalachian region has not yet afforded tin ores in commercial quantities, but shows promise of containing them.

ANALYSIS OF SOME FAIRMOUNT PARK WATERS.*

BY

MARTHA TRACY, B.A., M.D.

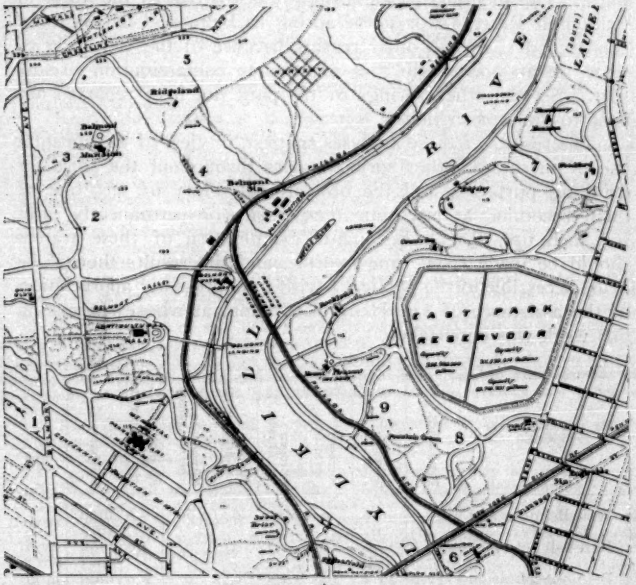
In determining the limits of Fairmount Park the authorities had in mind the prevention as far as possible of the pollution of the Schuylkill River. It was not possible to take land outside the bounds of Philadelphia County, nor to control the whole of the Schuylkill watershed within the county, but the commissioners were able to include several streams from source to outlet, and, as a result, within the territory are many springs and wells almost all of which probably derive their water principally from the subsoil at moderate depth. These sources have considerable sanitary importance, for not only are the springs used by frequenters of the park, but those near the park borders are resorted to very largely for the household supply of neighboring residents.

Notwithstanding these facts, but little information is available as to the composition of the water of the important sources. About fifteen years ago (JOURNAL OF THE FRANKLIN INSTITUTE, 1894, 137, 190) Mr. Reuben Haines published a statement of determinations of chlorine and nitrates in the waters of many of the springs, with general allusions to some other data, and remarks on the sanitary significance of the figures. It seemed of interest, however, to make a somewhat more complete analysis of the waters of some much-used springs.

The investigations presented herewith have been made during the past two months. The samples were collected with the usual precautions and the tests made as promptly as possible. The processes used were substantially the same as those in general use among American analysts, as set forth in the sixth edition of Leffmann's "Analysis of Water." The figures unless otherwise stated, are in parts per million. Quantitative determinations of the usual mineral ingredients were not made, but qualitative tests for calcium and sulphates were applied and the results are recorded in terms approximately descriptive.

* Contribution from the Chemical Laboratory of the Woman's Medical College of Pennsylvania.

With the exception of No. 1 all the waters were clear, odorless and tasteless. No. 1 was nearly colorless as delivered from the pump, but within half an hour became turbid and rapidly threw down a reddish precipitate found to be ferric hydroxide. The alkalinity of this when fresh, as noted in the table, was equivalent to 16.8 c.c. of N/10 acid per litre, but after blowing air through the water and thus precipitating the iron the alka-



Location of springs.

linity observed was 6.0 c.c. of N/10 acid. Though this water is free from ordinary contamination, the amount of iron present renders it unsuitable for drinking purposes. (See Table.)

The total solids are somewhat high in all the samples, but not above amounts frequently noted in hard waters.

From a sanitary point of view, however, the chlorine content of Nos. 2, 3, and 7, is especially to be noted. For subsoil waters such as these the upper limit of chlorine content in uncontami-

nated waters is usually placed at about 12 parts per million. The figures 24.0, 23.0, and 33.0, are, therefore, sufficiently high to arouse suspicion of contamination. These three springs are in close proximity to buildings and picnic grounds frequented continually by large numbers of people and the opportunity for contamination is obvious.

The nitrogen content of any of the waters is not unusually high. The alkalinity of all is slightly below that of the water of Schuylkill River. No. 4, the spring in Belmont Glen, is to be condemned if for no other reason, because of the collection of water in an open basin thus exposed to contamination of any sort. Several other springs of the park not here reported are open to the same criticism.

The results of these analyses suggest, in view of the constant use of these and other spring waters throughout the park for drinking purposes, and the obvious possibility of any one of them becoming at any time temporarily or permanently unfit for such use, that a systematic examination of these waters should be made from time to time, and the results thereof be made accessible to the public. I wish to express my appreciation of the assistance of Dr. Henry Leffmann, at whose suggestion this work was undertaken.

No. and Location of Spring.	Total solids.	Chlorine.	Nitrogen as nitrites.	Nitrogen as nitrates.	Nitrogen as ammonium.	Nitrogen by permanganate.	Alkalinity in c.c. of $\frac{N}{10}$ acid per litre.	Sulphates.	Calcium.
1. Well, Belmont and Elm Aves.	126.0	6.8	0	0	0	0.06	16.8	mod. am't.	
2. Baseball field	138.0	24.0	0	0.7	0	0	4.0	mod. am't.	mod. am't.
3. Belmont Mansion	142.0	23.2	0	3.3	0	0	2.0	mod. am't.	mod. am't.
4. Belmont Glen	60.0	9.2	0	0.8	0	0.032	2.0	trace	trace
5. Ridgeland	72.0	6.0	trace	1.3	0	0.032	4.8	mod. am't.	mod. am't.
6. Spring Garden Water Works.	170.0	13.0	0	2.4	0	0	4.0	mod. am't	mod. am't.
7. Strawberry Mans..	186.0	33.0	0	2.4	0	trace	5.2	trace	
8. Pump, Columbia Ave., entrance.	121.0	10.0	trace	1.8	0	0.043	6.0	mod.	trace
9. Below playground.	75.0	10.0	trace	0.8	0	0.04	2.4	trace	trace

NOTE—Figures are in parts per million except in the statement of alkalinity, which is in number of c.c. of N/10 acid per litre.

WOOD PRESERVATIVES USED IN 1908.

More than 56,000,000 gallons of creosote and nearly 19,000,000 pounds of zinc chloride were used in preserving timber in the United States last year. Small quantities of crude oil, corrosive sublimate, and other chemicals were also used.

These figures are based upon reports to the United States Forest Service of forty-four firms which operated sixty-four timber-treating plants. Assuming that on an average one gallon of creosote, or one-third of a pound of zinc chloride will protect a cubic foot of timber from decay, more than 100,000,000 cubic feet of cross-ties, piling, poles, mine, and other timbers were given a treatment that will greatly increase their life and usefulness.

Never since timber treating began on a commercial scale in the United States has the domestic supply of creosote been equal to the needs of the industry. With the rapid development of wood preservation in recent years, the insufficiency of the home production of creosote has become more marked. In 1908 almost seven-tenths—to be exact, 69 per cent.—of the creosote used by the treating plants was imported, and but 31 per cent. was obtained from domestic sources.

Nearly three-fourths of the imported creosote comes from England and Germany, some is obtained in Nova Scotia, and some in Scotland and Holland. The domestic creosote used by the treating plants was obtained chiefly in New York, Philadelphia, and other large cities.

Creosote is distilled from coal-tar, a by-product in the manufacture of illuminating gas and coke from bituminous coal. Not more than 20 per cent. of the coke used in the United States is made in by-product ovens. No coal-tar is recovered from the bee-hive ovens in which most of the coke is made; consequently the total production of coal-tar is far less than it would be with more conservative operations.

Were all the tar produced which the coal annually coked in the United States is capable of yielding, it would distil as much creosote as is now used by the wood preservers. Unfortunately, American operators do not even get the fullest use of the limited quantity of coal-tar made in this country, for it does not pay the operators to distil coal-tar for creosote alone; so, unless they can find a market for the associated products, it is not separated. Germany has gone far ahead of the United States in the development of coal-tar products, and her exports of them to this country are steadily increasing.

The zinc chloride used in wood preservation is all obtained from domestic sources, according to the report. Most of it is produced by a few large chemical companies.

Cross-ties are particularly liable to decay, since they are used under conditions which are favorable to the growth of the wood-destroying fungi. Consequently the railroads have always taken a leading part in timber preservation in the United States. Twelve of the forty-four firms which are operating timber-treating plants are railroad companies. The railroads also have many ties treated by commercial timber-treating plants.

Statistics upon the number of ties treated in 1908 have not yet been compiled. In 1907, however, according to Forest Products Bulletin No. 8, of the Bureau of the Census, the steam railroads of the United States used 19,192,000 treated ties, of which 11,217,000 ties were treated at their own plants, and 7,975,000 ties were treated at other plants.

The electric roads used 664,000 treated ties in the same year, nearly two-thirds of which were purchased already treated. The majority of the treated ties used by the steam railroads were preserved with zinc chloride, while with the electric roads more ties were treated with creosote than with any other one preservative.

Many telephone and telegraph poles are creosoted, and there is a growing use of treated timber by the most progressive mine operators. In many harbors, the only practical method of protecting piles from the destructive

teredo is to creosote them heavily. One of the most recent uses of creosoted wood on an extensive scale is for rectangular wooden block pavement. New York, Boston, Baltimore, Indianapolis, Chicago, and other large cities are using large quantities. Creosoted wooden blocks have been laid in front of the new terminal station building in Washington.

THE SMOKE NUISANCE.

REPORT BY THE UNITED STATES GEOLOGICAL SURVEY.

The smoke nuisance in cities seems to be not only a burning question but a question of burning—of combustion. A bulletin just published by the United States Geological Survey (Bulletin 373) on "The smokeless combustion of coal in boiler plants," by D. T. Randall and H. W. Weeks, gives the results of smoke studies carried on in thirteen large cities and of tests made at the Government fuel-testing plants at St. Louis and Norfolk. A preliminary report on the same subject was made in the Survey's Bulletin 334, "The burning of coal without smoke in boiler plants," by Mr. Randall, the edition of which is now exhausted. The report just published consists of 186 pages and 40 illustrations.

The conclusions reached may be summarized as follows:

Smoke prevention is possible. There are many types of furnaces and stokers that are operated smokelessly.

Any one kind of apparatus is effective only if so set under boilers that the principles of combustion are respected. The value of this requirement to the average purchaser lies in the fact that he is thus reasonably certain of good installation. A good stoker or furnace poorly set is of less value than a poor stoker or furnace well set. Good installation of furnace equipment is necessary for smoke prevention.

Stokers or furnaces must be set so that combustion will be complete before the gases strike the heating surface of the boiler. When partly burned gases at a temperature of, say 2500° F., strike the tubes of a boiler at say, 350° F., combustion is necessarily hindered and may be entirely arrested. The length of time required for the gases to pass from the coal to the heating surface probably averages considerably less than one second, a fact which shows that the gases and air must be intimately mixed when large volumes of gas are distilled, as at times of hand firing, or the gas must be distilled uniformly, as in a mechanical stoker. By adding mixing structures to a mechanical stoker equipment both the amount of air required for combustion and the distance from the grates to the heating surface may be reduced for the same capacity developed. The necessary air supply can also be reduced by increasing the rate of combustion.

No one type of stoker is equally valuable for burning all kinds of coal. The plant which has an equipment properly designed to burn the cheapest coal available will evaporate water at the least cost.

Although hand-fired furnaces can be operated without objectionable smoke, the fireman is so variable a factor that the ultimate solution of the problem depends on the mechanical stoker—in other words, the personal element must be eliminated. There is no hand-fired furnace from which, under average conditions, as good results can be obtained as from many different patterns of mechanical stoker, and of two equipments the one which will require the less attention from the fireman gives the better results. The most economical hand-fired plants are those that approach most nearly to the continuous feed of the mechanical stoker.

The small plant is no longer dependent on hand-fired furnaces, as certain types of mechanical stokers can be installed under a guaranty of high economy, with reduction of labor for the fireman.

In short, smoke prevention is both possible and economical.

NEWTON'S LAW AND THE CAUSE OF GRAVITATION.

BY

OWEN ELY,

St. Paul, Minn.

NEWTON'S law has always been regarded as the most fundamental doctrine of nature—as it were, the back-bone of science. So well-grounded on a basis of fact has it seemed that little attempt has been made to determine whether a rigorous demonstration of its concepts is theoretically possible, or whether it includes all possible factors in the operation of gravitation. Yet it is perhaps true that through respect for the genius of Newton science has neglected to continue the work which he began and which the progress in physics since his time enables us to test more carefully and investigate more fully. An analysis of the law in the light of recent development of physical knowledge is, then, essential to determine what corrections or omissions may now be apparent in his statement of the one universal interaction of matter.

The first words, "every particle in the universe," indicate an unlimited application of the law which can never be proven true. Robert Ball has shown that there is a reasonable probability of its truth from the facts within our reach, but "when the law of gravitation is spoken of as being universal we are using language infinitely more general than the facts absolutely warrant. At the present moment we only know that gravitation exists to a very small extent in a certain indefinitely small portion of space."[1]

The words "attracts every other particle" express an assumption which, while apparently upheld by observation and facts, is directly contrary to the law of conservation of energy. We know that gravitation is a force by the definition of the latter, for it causes changes in the motion of bodies: it is not an "absolute" or "inherent" property of matter, as Newton himself recognized: "That gravity should be innate, inherent, and essential to matter . . . is to me an absurdity. Gravity must be caused

[1] Popular Science Monthly, vol. 23, p. 94.

by an agent acting constantly according to certain laws." We know, then, that gravitation is the space-rate of transferring energy from one particle to another. If one particle attracts every other, it can easily be seen that after all the waves of force sent out by it have met and acted on some other particles, a greater number sharing the division as the square of the distance increases, they would continue beyond the sphere of these particles and influence other spheres of matter without. Thus the original amount of energy sent out in these waves would be wholly transferred to other particles not only once but twice or a million times.

In the case of an infinite universe it is apparent, as the writer has shown,[2] that with Newton's gravitation no particles could come together to form masses because of the infinitely great attraction on all sides of a particle.

To understand just how gravitation is transmitted only between the particles of matter and is not "lost" within a short space as is the cohesive attraction of the molecules, we must remember that matter is not dense, as our senses would tell us—for sense impressions are only the transference of energy received from matter, and do not give us a description of matter itself. We know that the bulk of the molecules of a gas occupies only the 1000th to the 10,000th part of its volume; that the atoms are loosely grouped within the space known as the molecule; and that the newly-discovered electron in its atom is "like a mouse in a cathedral": hence we may liken a piece of matter to a universe, composed of its planets, systems, and groups of systems—and better comprehend how the ether wave emanating from a particle, like the light from a sun, would travel an enormous distance before the last fraction of its ever-widening front would be obliterated by a particle lying in its path.

One known fact concerning the ether also tends to corroborate this conclusion: the earth passes through the ether with a velocity of many miles per second without apparently causing any motion of the latter, and hence producing little displacement. Conversely, then, waves in the ether could pass through the earth without meeting great opposition.

In considering the action of other ether waves passing through matter,—the opacity of matter to light, for example,—we must remember that such waves are caused by molecules as

[2] Popular Astronomy, vol. 16, p. 435.

units and affect molecules. Now it is probable that neither the molecule nor the atom is the gravitational particle, because of the varied relations between the molecules and the atoms of different substances, constituting most of the properties of different matter; but the electron, apparently alike in all forms of matter, is the unit best adapted to be the gravitational particle, since there could be but one interaction between electrons, and that would be common to all matter. It is possible, also, that the ratio of the gravitation wave to the light wave is that of the electron to the molecule; and thus the latter wave would traverse a distance inconsiderable with the former's before destruction.

Professor Seeliger has demonstrated mathematically that Newton's law will not hold for a homogeneous distribution of matter, and adduces the testimony of Carl Neumann who "correctly designates the demonstrated consequences of Newton's law as absurd and concludes from it that the law of attraction leads to contradictions in the case of an homogeneous distribution of matter." [3] Professor Seeliger further proves that "with any conceivable mode of mass-distribution whatever . . . the introduction of arbitrarily small, though finite corrections to Newton's law, which need become appreciable only when vastly extended regions of space are considered," [4] is necessary for its validity. Professor Seeliger's "variation" may be considered identical with the change in operation of Newton's law after the introduction of the new factor which has been explained.

But aside from theory, one may ask, why is there no apparent or measurable variation in the action of gravity or in celestial phenomena which could be traced to this factor as a cause? In regard to the movements of stars and planets, where the cumulative effects of the "variation" should be evident, there are indeed many "little discrepancies between observed and computed motions" which have led Professor Simon Newcomb to accept as "provisionally acceptable and more unobjectionable than others that have been proposed," [5] the hypothesis that the attraction differs not as the square of the distance but in a manner differing slightly from the square. Now it is evident that this hypothesis, if true, is explainable only in that the ether absorbs

[3] Popular Astronomy, vol. 5, p. 474.
[4] Idem, p. 546.
[5] 1895 Memoir, "The elements of the four inner planets," etc.

some of the gravitational energy (in which case how can it be inert and transmit light waves so perfectly?) or that gravitation-waves meet an obstruction in space, which would be matter.

Another answer to the question is that we do not actually know what weight is. For weight is supposed to be exactly proportional to mass, while we know no means of measuring mass but in terms of weight: we measure amount of cause in terms of amount of effect and have no proof that the former is equal to the latter. Hence, we cannot assert that there is proof against the contention that every particle in the earth attracts only those other particles between which and itself there is no intervening particle.

This idea that weight may not, after all, be perfectly proportional to mass, suggests another possibility which Newton's law neglects. This is that another factor may enter to a small extent into the determination of weight—the kinetic energy of the particle. This has already been suggested by several writers: "All bodies are continually sending waves out into space and this wave energy is proportional to the total kinetic energy of the body. . . . The total internal kinetic energy ought to be a factor as well as the mass."[6] "One of the cardinal doctrines of gravitation—that attraction is proportional to mass—remains unproven . . . which leads to the inference that weight is not an invariable property of matter. . . . It may be possible to bring the particles into such a condition that the gravitational attraction is lessened or altogether annulled." Indeed, there are strange difficulties in giving places in the periodic system to the elements helium and argon on account of the atomic weights, and Professor Ramsey has recently suggested that temperature or peculiar electrical condition may make atoms heavier or lighter than they would otherwise be.

Let us see what clues as to the ultimate cause of gravitation may be gained from a few facts which recent physical investigation has placed before us. In the first place, for the reasons cited, we will consider the electron as the gravitational particle. As gravitation is the direct action of an ether wave on matter, the cause of this wave must have been a motion of the gravi-

[6] Popular Astronomy, vol. 13, p. 8.

[7] Acad., vol. 51, p. 540: Review of "Some Unrecognized Laws of Nature," by Ignatius Singer and Lewis H. Berens.

tational particle. Now we know that the electron has an orbital motion: "To explain all the properties with which we know the chemical atoms to be endowed, and more especially their power of complex radiation, it is necessary to represent an atom as a structure containing a large number of electrons in steady orbital motion around each other, somewhat as the planets move within the solar system. . . . The emission of corpuscles from the radio-active elements also indicates such movement, for it is unlikely that the high velocities with which the corpuscles are hurled away should have been impressed on them at the instant of ejection. . . . If an atom consists of a system of electrons in orbital movement, the acceleration of their motion must involve a constant radiation of energy. . . . A structure like an atom, with its mass-acceleration balanced, would maintain its energy with very little loss for long periods of time, measured, perhaps, in millions of years. Still, loss of energy does occur," the cumulative effects being probably "an explosive disintegration of the atomic system, such as occurs in the phenomena of radio-activity."[8] How else can this loss of energy in the electron be accounted for—since no energy can be "lost"—but to consider it the cause of gravitation, and what better explanation of gravitation can be found?

In order that the revolving electron set up a wave motion in the ether (which is the only way in which its energy can be disseminated) the latter must be composed of particles far smaller than the electron—the ratio of size being less, probably, than that of the electron to the molecule. We know this to be true, for if the ether-particle is also an electron, inert and dissociated (which would be the limit of a chemical conception of the ether) or a larger particle (which we can only imagine as composed of electrons), gravitation would act on ether as well as on matter. This would probably make changes in its density throughout space and cause measurable effects in light waves.[9] Another

[8] The Recent Development of Physical Science, W. C. D. Whetham, pages 256, 282, 284, 285.

[9] In the Philosophical Magazine for November, 1885, Prof. De Volson Wood, in an article on "The Luminiferous Ether," considered ether as a gravitational gas and concluded from a mathematical investigation that it might still be regarded as having very nearly uniform density throughout all space. However, Luigi D'Auria has pointed out (Popular Astronomy, vol. 15, p. 101) that through a fatal error in reasoning this conclusion is untenable, and thus gravity does not affect ether.

reason is apparent: the passage of the earth through the ether would result in collisions between "matter-electrons" and "ether-electrons" which would produce noticeable effects on matter.

It remains to consider the manner in which the ether wave affects particles in its path and causes them to move in a direction contrary to its own. First let us examine some phenomena which apparently present a fine analogy to gravitation. Two tuning-forks, when set in vibration in the atmosphere, are found to attract each other; and one of them alone will attract any substance heavier than the air, while it repels one that is lighter. The action of the forks and its cause is discussed by F. J. B. Cordeiro,[10] who attributes the attraction to the form of the sound wave set up by the vibrations. "The crests (of the wave) are all pointed forward and the hollows backward—something like the teeth of a saw. The period of compression is accomplished more quickly than the period of expansion—the face of the wave is steeper than the back," from two causes, viz., "the motion of inertia of a particle of the medium is more quickly overcome during the compression stage than during the expansion stage because it is opposed by a greater resistance in the first case than in the latter; added to this the composition of the motion of oscillation with the wave motion would tend to give the crests a forward tilt. . . . The front of a sound wave striking a heavy body tends to repel it, while the back of the wave tends to push it back. . . . On particles denser than the medium, the effective backward acceleration exceeds the forward acceleration and such bodies are therefore urged in a direction opposite to that of the wave motion. On particles less dense than the medium the effective forward acceleration exceeds the backward acceleration and such bodies are urged along with the wave motion." He then compares gravitation to the attraction of the tuning-forks and concludes that the loss of atmosphere by the earth and other planets may be attributed to the repulsion of "gravitation" above the point where the air has the same density as the ether, calculated by the best authorities to be 10^{-17} that of water, which point in the case of the earth is thought to be about 210 miles above the surface. He also considers the repulsion of

[10] Popular Astronomy, vol. 13, p. 8.

comets' tails, as they approach the sun, to be caused by this negative gravitation of that body.

In comparing the electron in its orbital motion to the vibrating fork and the ether waves of gravitation to the air waves of sound, the identical effect in both cases seems to justify the conclusion that the manner of action of gravitation has been discovered. And it seems probable that this theory is fundamentally correct, unless it contradicts a known fact or contains a fallacy in reasoning: at least, why not accept it until a more useful one be promulgated?

To sum up, then, the defects or omissions in Newton's law: it is too unlimited in application and should be modified slightly so as not to pass the bounds of our knowledge; in one particular it violates the law of the conservation of energy; it does not name the particle as a physical unit; it neglects a possible factor, the kinetic energy of the particle; it does not even suggest the need of a medium for transmission of the force; it does not specify the nature of the attraction or attempt to name its cause. Newton's law was, at the date of its enunciation, a wonderful demonstration of truth in that it correlated a thousand mysterious phenomena and denoted a common cause for all of them; but Newton's mind conceived only an explanation of the first effect apparent to the senses in the chain of phenomena in which that effect is only a culmination. To name the links, as it were, in this chain, we should designate: the unknown cause which sets the electron in motion; the effects of this motion on the ether; the nature of the ether, by which it transports, without absorbing, the energy given it; the effect of this energy wave on particles of matter, explained by the nature of the wave and the relation of the particle to the medium; the effects of gravitation—pressure, heat; and the dissemination of heat through space, tending toward an ultimate uniform distribution of unavailable energy. Newton's law, then, with the essential corrections, may serve merely as a statement of the fact of attraction and of those causes which are purely of observational significance; but it cannot be used to represent the sum of our knowledge of the forces and causes behind gravitation, and for this purpose we need a law modelled according to the present scope of our information. A statement such as the following would indicate the *statu quo* of the problem: All known matter consists of electrons having

one common interaction as follows: there is a gradual, uniform transmission to the surrounding ether of the kinetic energy of the orbital motion of the electron within the atom, this lost energy being perfectly transmitted in all directions by a wave motion of ether particles, which are of a smaller order of size than the electron, are at a distance from each other and have no motion of their own; the ether wave transfers its energy to the electrons it meets, in that because of its form (comparable to that of a Koenig "manometric flame") it causes them to move in a direction opposite its own, or toward the particle which originated it, constituting the phenomena of "gravitation": which, as is thus evident, has for its factors, in the case of two electrons, about $^2/_{15}$ of the whole force radiated by an electron,[11] divided by the square of the distance in units of the electron's radius; and in the case of a number of electrons, "gravity" or weight has the same factors, multiplied by the product of the numbers of electrons in the two bodies (the earth and any other), from which product is subtracted the number of electrons each of which is in a straight line with any two others (since the attraction in such cases is spent on the interposed particle).

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[11] Since, assuming the electron spherical in shape and considering two of them at a distance of one radius or unity from each other's centres or touching each other (representing the wave as coming from the centre of sphere 1 as in the figure), the area of the zone XNY on the surface of sphere 1 is that part of the whole spherical wave intercepted by sphere 2 which

$= 2\pi \times MN$

$= 2\pi \times (1 - \cos\theta) = 0.26794\pi$

$$\left(\text{since } \frac{AO'}{OO'} = \theta = 30^\circ\right)$$

$$= \frac{.26794\pi}{4\pi r^2} = 0.06698 = \text{nearly } \frac{1}{15} \text{ of whole surface or whole wave.}$$

Similar action taking place between 2 and 1, the sum of the two is $^2/_{15}$

The task of explaining gravitation and the unseen phenomena behind it is only begun: for the difficulties of experimental research into the ultimate nature of ether and matter make the solution dependent upon the results of years, perhaps centuries, of patient inquiry. Thus is emphasized the importance of the logical evolution of theory through rigorous elimination of fallacy and by "the survival of the fittest": for it is only by constant and careful development of theory that we can best maintain the correct conclusions from the relations of newly ascertained facts to old ones, and by so doing blaze the path by which science through experimental investigation may reach a final and direct demonstration of the truth.

And we know that when the secrets of ether and the electron are at last discovered we may be able to convert the atom's enormous potential energy, now dormant and unavailable, into power superfluous for man's desires; and when we find a means to counteract the effect of the ether waves which we call gravitation we can without effort fly to the planets and investigate all the depths of space.

RUBBER-ASPHALT ROADWAYS.

The following information concerning rubber-asphalt pavements in France has recently been published by the Department of Commerce and Labor.

Experiments, covering periods of six years, have been made with this pavement in several cities throughout France, including Paris and Lyons, and as far as can be ascertained have given good results.

In the city of Marseilles a satisfactory experiment was made upon the Prado a number of years ago, and this spring three or four public places were similarly paved, these areas, however, being devoted to pedestrian traffic exclusively. Innovations of this kind make slow progress in France, but from the character of the men interested in the company and the increasing importance of the work undertaken rubber-asphalt paving must be regarded very seriously as a substitute for the more usual form of asphalt paving.

At the present time most asphalt paving involves the use of costly installations for the heating of the powder, a considerable amount of material, and a special class of laborers, all of which tend to increase the cost. Under the new process it is possible to make cold applications of asphalt, which are said to possess all the advantages of hot compressed asphalt without its drawbacks.

MATERIAL USED AND ITS APPLICATION.

The material under description is a product resulting from the association of asphalt and rubber. Asphalt is a carbonate of lime impregnated with bitumen, with which rubber combines under certain conditions, thus effecting the cohesion of the calcareous molecules. This product is claimed to be more plastic and more adhesive than pure asphalt, and to resist higher temperatures. To obtain the combination of bitumen and rubber they must be energetically mixed in special devices, in which the asphalt, reduced to fine powder, is in

the presence of rubber swelled and softened by a solvent. The material thus obtained is a brown powder darker than the original asphalt, and it suffices to compress it in order that it shall set and harden rapidly.

It is alleged that when asphalt is applied hot, the heat of the application coming into contact with a concrete foundation containing more or less humidity vaporizes the water contained therein, and the steam, by its force of expansion, escapes, thus destroying the compactness of the combination. This inconvenience does not present itself in the system under designation, which permits the application of a much thinner layer of asphalt and one which unites itself with the concrete, constituting a solid mass. The observations of this form of pavement satisfy those interested in the subject that the completed surface resists ordinary wear more satisfactorily than any other.

RUBBER-ASPHALT PAVEMENTS.

Rubber-asphalt must be applied upon a foundation of first-class concrete, consisting of 440 pounds of good Portland cement and 1 cubic meter (35.31 cubic feet) of pebbles and sand, the proportions being one-third of sand to two-thirds of pebbles. The thickness of the foundation should vary from 15 to 20 centimetres (5.90 to 7.87 inches) and it should be rammed with the back of shovels used in this work, and given the exact form which the roadway is intended to have, without the necessity of making later additions of concrete to bring the surface to its proper proportions. The surface of the concrete should be regular, so that the layer of asphalt may have a uniform thickness. This foundation should remain three to five days, according to the season, until it has required a sufficient hardness to support the ramming of the layer of asphalt. The surface of concrete having been well cleaned, is covered with a thin coating of special material, which is laid on with a brush upon which the rubber-asphalt powder is lightly sprinkled. Shortly after these preliminary operations the uniform layer of rubber-asphalt powder is spread to a thickness of 3.5 to 4 centimetres (1.37 to 1.57 inches), which is compressed progressively by means of a rammer. This done the surface may be opened immediately to travel. It is said that by this process the top-dressing of asphalt, when laid on hot, may be one-half the thickness necessary when the asphalt is laid on cold.

As the process is covered by a patent, and exploited by a particular company, it is impossible, of course, to describe the system otherwise than in these somewhat general terms.

BUILDING OPERATIONS IN 1908.

The total cost of the buildings erected in the principal cities of the United States in 1908 was $546,467,390, according to Jefferson Middleton, of the United States Geological Survey, who has collected statistics on this subject in connection with his investigations of the clay-working industries. In 1907 the cost of buildings in these same cities reached a total of $626,-148,890. The decrease in cost in 1908 therefore amounts to $79,681,500, or 12.73 per cent. The following table shows the number of permits issued and the cost of buildings erected in each of the cities

RANK OF CITIES.

The relative rank of the cities in cost of building operations is interesting. New York is first, the cost of its buildings exceeding the cost of those of its closest competitor, Chicago, by $50,584,582, or more than 75 per cent. If the cost of operations in Brooklyn, the third city in rank, is added to that for New York, the total will be $163,684,622, or 30 per cent. of the cost of the building operations of the 49 cities included in the table. San Francisco is fourth in rank, Philadelphia is fifth, and St. Louis is sixth. Seventh in rank is the small though rapidly growing city of Seattle, which spent more for buildings in 1908 than Pittsburg, which was eighth, Boston, which

BUILDING OPERATIONS IN THE LEADING CITIES OF THE UNITED STATES IN 1908.

	Number of permits or buildings.	Cost of buildings.		Number of permits or buildings.	Cost of buildings.
Allegheny, Pa	(a)	(a)	*Carried forward*	79,631	$235,135,020
Atlanta, Ga	4,153	$4,833,941	Milwaukee, Wis	4,169	10,063,669
Baltimore, Md	2,893	7,554,709	Minneapolis, Minn	5,638	10,093,915
Boston, Mass	2,632	11,253,712	Nashville, Tenn	4,215	1,969,505
Brooklyn, N. Y	10,769	45,865,240	Newark, N. J	2,419	7,161,668
Buffalo, N. Y	2,788	6,847,000	New Haven, Conn	919	3,091,465
Cambridge, Mass	425	2,153,070	New Orleans, La	2,457	5,744,311
Chicago, Ill	10,627	67,234,800	New York, N. Y	6,103	117,819,382
Cincinnati, Ohio	3,553	6,428,888	Omaha, Nebr	1,526	4,590,650
Cleveland, Ohio	6,674	9,896,869	Philadelphia, Pa	13,363	28,152,265
Columbus, Ohio	1,698	3,400,273	Pittsburg, Pa	a 4,023	a13,136,387
Dayton, Ohio	1,193	3,234,280	Providence, R. I	1,386	4,034,000
Denver, Colo	3,117	10,098,020	Reading, Pa	571	497,700
Detroit, Mich	3,662	10,682,170	Richmond, Va	1,330	3,169,431
Fall River, Mass	399	1,140,927	Rochester, N. Y	1,302	4,975,317
Grand Rapids, Mich	1,064	2,181,759	St. Joseph, Mo	678	1,717,723
Hartford, Conn	676	3,107,348	St. Louis, Mo	9,119	21,190,369
Indianapolis, Ind	4,013	5,895,928	St. Paul, Minn	.....	7,625,538
Jersey City, N. J	1,367	4,490,466	San Francisco, Cal	6,729	31,668,341
Kansas City, Kans	792	1,108,472	Scranton, Pa	892	2,366,405
Kansas City, Mo	3,840	10,562,041	Seattle, Wash	7,901	13,777,329
Los Angeles, Cal	7,371	9,931,377	Syracuse, N. Y	1,291	3,327,195
Louisville, Ky	2,909	2,914,141	Toledo, Ohio	1,065	2,081,448
Lowell, Mass	497	1,019,081	Washington, D. C	5,358	10,800,996
Memphis, Tenn	2,519	3,300,508	Worcester, Mass	1,102	2,286,361
Total	79,631	$235,135,020	Total	163,087	$546,467,390

a Allegheny included in Pittsburg, Pa.

was ninth, and other cities much larger. This great activity in Seattle is ascribed to the extremely low prices of building material and labor.

CHARACTER OF BUILDINGS.

Of the permits issued or buildings erected 38.64 per cent. were for buildings of fire-resisting materials, and 61.36 per cent. for wooden buildings, corresponding closely to the percentages in 1907. The average cost of brick or fire-resisting buildings in 1908 was $9,089 and of wooden buildings $2,101.

Chicago reported the largest number of brick buildings—8,208, with an average value of $6,818; Philadelphia the next largest number—6,778, with an average value of $3,308. Brooklyn reported the third largest number of brick buildings and New York the seventh, though in cost of buildings of this class it is first. New York reported 1,884 brick buildings costing $103,064,486, or nearly twice as much as Chicago's 8,208. The average cost of fire-resisting buildings in New York was $54,705. No wooden buildings were erected in the borough of Manhattan, those reported for New York being in the Bronx. The largest number of permits for wooden buildings was issued in Seattle—7,777, the average cost of the buildings being about $1,000. The next largest number of wooden buildings was reported by Los Angeles—4,679, costing on an average $1,383. The greatest cost for wooden buildings was reported by San Francisco, the average cost being $3,641. Chicago, which reported the largest number of brick buildings, was eighth in number of wooden buildings. Except for Reading, where none were erected, Philadelphia reported the smallest number of wooden buildings—45, with an average cost of $1,482.

REPORT IN PREPARATION.

A report on the clay-working industries of the country, including statistics of the building operations, is now being prepared by Mr. Middleton and will be issued by the Survey within a few months.

ELECTRICAL SECTION

(Stated meeting held Thursday, February 11, 1904.)

THE CORROSION OF METALS UNDERGROUND BY ELECTROLYSIS.

BY

A. A. KNUDSON, Elecl. Engr.

THE object of this paper is to set forth somewhat briefly the present status of electrolytic action upon subsurface metals due to railway currents, and to illustrate with some items gleaned from practice the movements and effects of such currents.

Attention will first be given to some features pertaining to the *cause* of railway currents flowing into and following underground pipes and other metals and afterwards consideration to some of the destructive *effects* from this cause.

A glance at the construction of the single trolley system will first be made in order to fully appreciate the results of such construction upon underground metals.

It is fairly well known that the single overhead wire reenforced by copper feeders carries the current to the cars, thence through the motors and wheels to the *rails* which are employed to return this current to the power house. As is well known the rails are buried to their top surface in the soil, and therefore this side of the circuit is permanently "grounded." Here is where the trouble from electrolysis comes in, for in the same soil in the average city and town, a few feet below the surface there is a gridiron of water-mains and a gridiron of gas mains, besides other metallic conductors. Under the law of divided circuits these underground mains represent other paths by which a portion of this current is bound to flow and, therefore, it divides itself among them all, some passing by the way of the rails and their auxiliary feeders when they are provided and some by the way of mains, in the inverse ratio of their several resistances in accordance with this law, the damp soil acting

as the conducting medium between the rails and mains. Where the current *passes out* of these mains to the soil on its way to some neighboring main, or to some water-course leading to the power house, or again to the rails in the vicinity of a power house, electrolytic action, commonly called electrolysis, takes place, resulting in the destructive effects which are now quite familiar.

The condition *of the track circuit* has much to do with the proportion of current that may leave it and pass into the mains. With heavy 90 and 100 pound rails well bonded and with auxiliary copper feeders a much less amount will pass off to other paths than if the rails are light and poorly bonded, with no feeders. The former construction is generally found in the central or busy parts of a city while the latter usually prevails on the more distant sections or suburbs. If the entire track circuit in a city were constructed as in the former case it would not mean perfect immunity from electrolysis, as some current even then would pass by way of other indirect paths underground.

We shall endeavor to illustrate with views divided in two groups both the *cause* and *effect* of electrolytic action; the first group represents the cause, and some of the peculiar current movements underground will also be referred to, while the second group will refer to effects or damage to mains and other metals.

CAUSE OF ELECTROLYSIS

Fig. 1 is a typical map and illustrates the usual flow of current upon mains in any city where the single trolley system is in operation; with the power house located upon the bank of a river or other water-course.

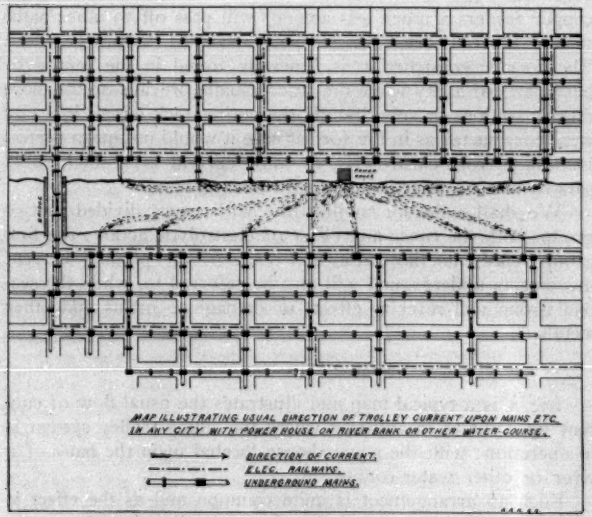
Such an arrangement is quite common and as the effect is much the same among them all so far as the direction of currents are concerned we have chosen this method of illustrating a number of cases.

It will be noticed that not only do these currents flow across the river to the power house but also along the banks of the side upon which it is located.

A water or gas main as indicated at *A* passing across a river bed is one path for a returning current often found. Such pipe is quite likely to be damaged by electrolysis, particularly

if in salt water, as when it conveys current some is sure to leave it and pass into the mud bottom or river, thence to the power house by way of the pipes used for condensing. This *back door* entrance in many cases is a matter of much concern to railway companies, passing as it does into the intake pipes, thence through steam and condensing apparatus, resulting in electrolytic injury and often necessitating extensive repairs. This effect may be fairly termed the "boomerang" of the single trolley system.

FIG. 1.


MAP ILLUSTRATING USUAL DIRECTION OF TROLLEY CURRENT UPON MAINS ETC. IN ANY CITY WITH POWER HOUSE ON RIVER BANK OR OTHER WATER-COURSE.
DIRECTION OF CURRENT.
ELEC. RAILWAYS.
UNDERGROUND MAINS.

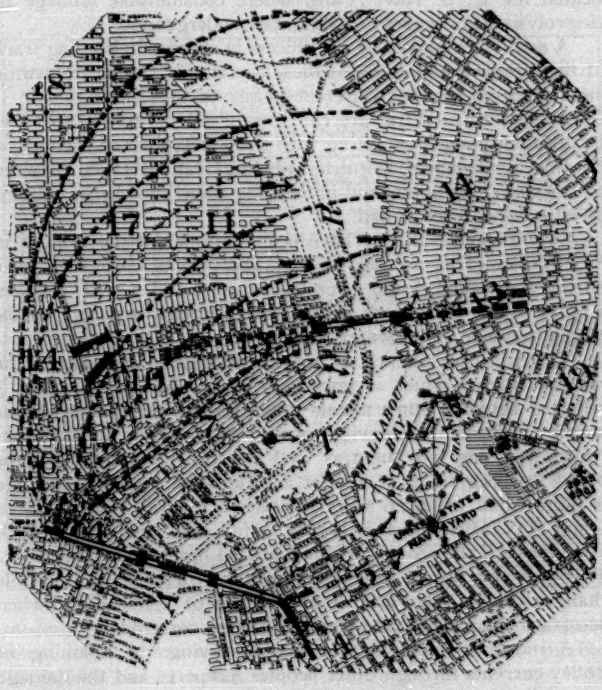
It has been found that a considerable proportion of trolley current will seek a river or other nearby water-course in preference to following an underground main or even the railway track return whenever the conditions offer an opportunity.

New York City.—The next illustration (Fig. 2) of straying currents is a section of New York City showing the flow to be over the Brooklyn Bridge to Manhattan Borough, thence through the underground metals to and over the new or Williamsburg

bridge, thence over that bridge and returning to the power house in Brooklyn at Kent Avenue through underground mains in Brooklyn.

Before the new bridge was built this current spread as far north as 23rd Street, about 2 miles, before entirely crossing as

FIG. 2.



shown by the lines and arrows. Now, however, the new bridge with its mass of metal is acting as a "short circuit" and most of the current recrosses the river through it.

One test for current flow was made upon the Brooklyn side of the new bridge upon a 6-inch water pipe coming down from

the structure and a maximum of nearly 70 amperes was found passing through it directly into the water mains and thence towards the Brooklyn Power House. This however was only one path; there are many others, such as the metal foundations of the pillars where the current may pass out into the soil and cause electrolytic action. In this same section of New York is located the U. S. Navy Yard, where considerable damage by electrolysis has occurred to the pipes underground.

A method employed by the officers in charge, in keeping track of the direction and force of these currents is through potential measurements between different points of the Yard.

Navy Yard.—Wires are run from a central station to 12 or 13 different points connecting with the water pipes at each place. By this arrangement voltmeter readings can be taken between any two of these points and in this way some knowledge of their direction and force is had.

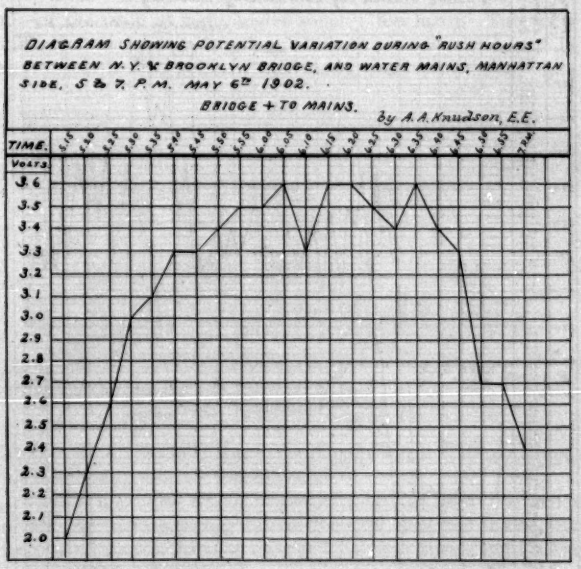
Several potential tests have been made about the bridges in New York. The one recorded by Fig. 3 was taken last April during a so-called "rush hour" between 5 and 7 P. M. between a pillar of the New York and Brooklyn bridge structure on the Manhattan side and a water main.

This will give an idea of how the change in strength of the railway current which is governed by the changes in traffic is reflected between other metals underground. The bridge was positive to the mains, showing currents coming over from Brooklyn and passing into them as well as other metals. It will be noted that beginning at 2 volts a little after 5 o'clock the rise is quite rapid until 3.6 volts is reached several times between 6 and 6.35, after which it begins to fall off, when at 7 o'clock after most of the crowd has been carried home it is back to 2.4. This rise and fall of potential therefore corresponds to traffic changes on the cars and is one means of establishing when necessary the identity and source of these currents.

A more complete method for observing the roaming of trolley currents through other peoples' property and the damage caused, is by *current measurements* upon the mains. This is often conveniently ascertained by the drop of potential test in a given number of feet upon a known size of pipe, the resistance of which has been previously determined, and by the application of Ohm's law the flow of current in amperes is found.

In many cases permanent stations are now installed upon important mains by screwing into them brass plugs, usually 10 feet apart, to which are attached insulated wires; these are led to the surface of the street and the ends secured in a box. By this arrangement periodical tests are made, and a record kept of the current in amperes, which is found by millivoltmeter

FIG. 3.

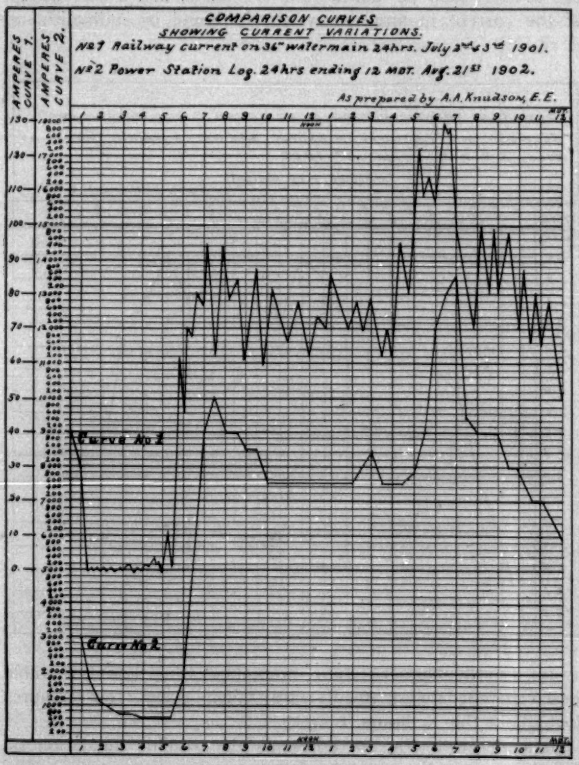


readings in the manner stated. Sometimes when found desirable these current measurements are taken every few minutes throughout the 24 hours.

The diagram Fig. 4 represents the graphic tabulation of these readings taken upon a 36 inch water main and also upon the same map a second curve line is placed giving the "load" line or "log" of a power house; the readings of both are placed at the same hours. The purpose of this illustration is to show

at a glance how the variations of current strength upon the railway lines is faithfully reflected in the variation of current strength upon underground mains, it will be noticed that the

FIG. 4.

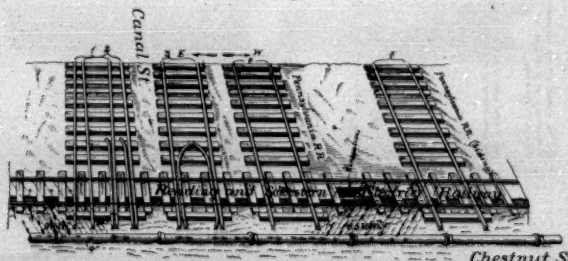

COMPARISON CURVES
SHOWING CURRENT VARIATIONS.
No 1 Railway current on 36" watermain 24hrs. July 3rd & 3rd 1901.
No 2 Power Station Log. 24hrs ending 12 MDT. Aug. 21st 1902.
As prepared by A.A. Knudson, E.E.
AMPERES CURVE 1.
AMPERES CURVE 2.
Curve No 1
Curve No 2

high and low readings occur at precisely the same hours of the 24, thus completely identifying the current. The periodical tests which are carefully compiled in tables are kept as records for

future use, so in case it is found that important mains have been badly depreciated by electrolysis by currents flowing through them, a city or water company would be in a position to fix the responsibility.

Another effect of the movements of underground current is its transfer from one pipe to another underground. This occurred in an 8 inch water main, and two 6 inch wrought-iron pipes used for conveying oil to the seaboard passing over the top of the main at right angles about 3 feet apart. The water main for about two lengths (25 feet) was nearly ruined by electrolysis at this point, it was found positive to the oil pipes,

FIG. 5.



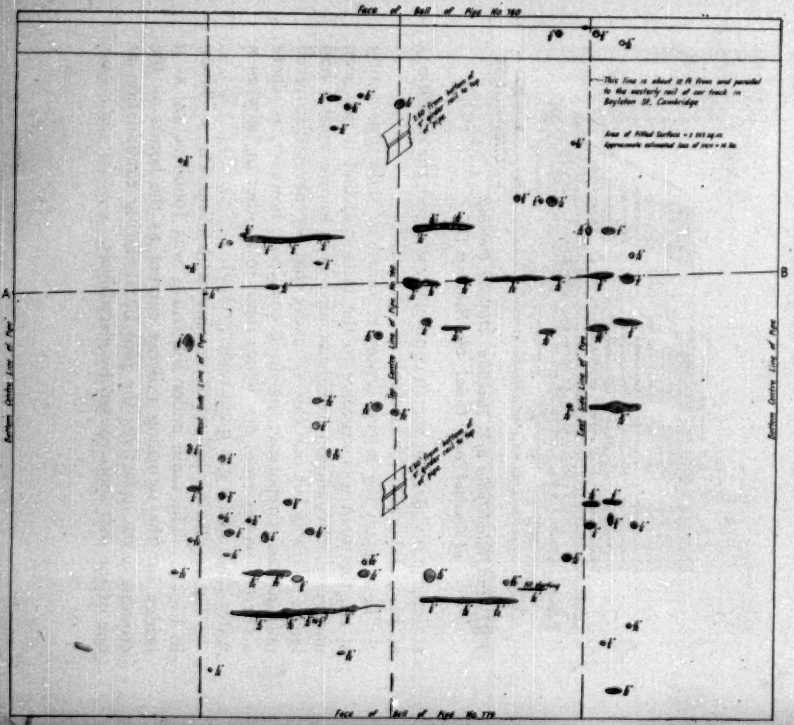
P.R.R. and Philadelphia and Reading Railway Crossing at Chestnut and Canal Sts. Reading, Pa.

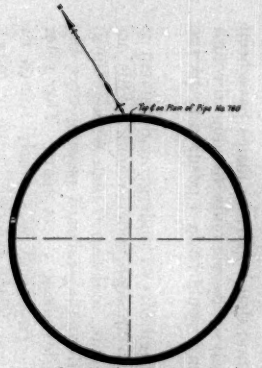
at times to 6 volts, and was in continually wet soil, the conditions all being favorable for electrolysis.

Tests upon the street, however, failed to show this action at all, the main was negative to the rails, and had it not been uncovered its condition would not have been known until it had burst. This is but one case of many that are never discovered until a leak is reported; the usual condition, however, is where a current passes from one water main to another or between a water main and a gas main underground.

The result of a bad track crossing at Reading, Pa., is shown in Fig. 5. The main under the tracks was found acting as a bridge for the returning railway current as the bonds on the crossing were defective; the pipe burst during examination at one of the soft spots caused by electrolysis.

FIG. 6.


Face of Bell of Pipe No 780
This line is about 10 ft from and parallel to the westerly rail of car track in Boylston St. Cambridge
Area of Pitted Surface = 2 333 sq in.
Approximate estimated loss of iron = 16 lbs.
Face of Bell of Pipe No 779
A
B
Bottom Centre Line of Pipe
East Side Line of Pipe
West Side Line of Pipe



Section of 48"Pipe on AB

About 85% of the pittings on this pipe are indicated on this plan, the others are less than ¼" in diameter or than ¼" in depth and were not located

Commonwealth of Massachusetts
Metropolitan Water Works
Distribution Department

Plan of Surface of 48" Pipe No. 780 showing location and depth, on Nov. 24, 1902, of Pittings caused by Electrolysis.

Pipe laid Sept. 5, 1898 under centre track leading to Car House of the B. E. Ry Co on Boylston St. near Eliot St. Cambridge.

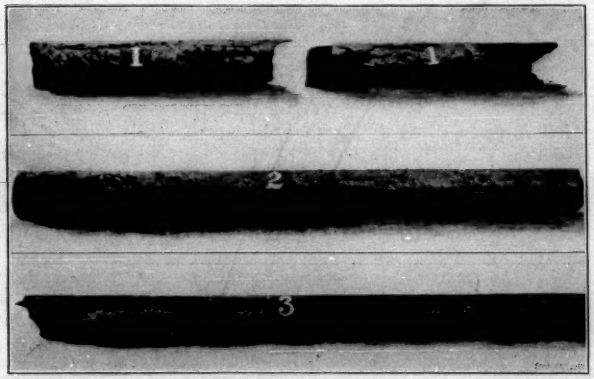
Scale, 2 in. = 1 ft. Dec. 5, 1902.

The preceding illustrations all refer to the *cause* of electrolytic action upon mains. We will now turn our attention to the other feature of the case and with a few views illustrate the *effect* upon underground metals.

EFFECT OF ELECTROLYSIS

There are two distinct phases of electrolytic action upon underground mains; one is the *lateral* effect, where the current in passing out from the body of a main causes pitting and dis-

FIG. 7.



integration of the iron, the other is the effect of current flowing *through* a main, causing damage at the joints.

First, as to the lateral effect. In cast-iron mains soft spots or furrows form, which are filled with carbon similar to an artificial graphite. In steel or wrought iron the effect is a shredded appearance with but little carbon.

Figs. 6, 7 and 8 show some lateral effects. The first is a reproduction of a photograph which was made from a drawing and represents a number of these pittings, about eighty in all, ranging in depth from ⅛ of an inch to 9-16. This drawing was made from a careful examination of a 12 foot length of a 48 inch cast-iron main and is a plan view of the entire surface, it shows not only every pitting but their size and shape, with the

depth marked at each one. Most of the data is marked upon the plan, but the following will be of interest.

Difference of potential between pipe and rails 5 to 15 volts,—15 volts occurring at peak load—daily average 8 volts. Current flow on the main 5 to 95 amperes, daily average 50. Distance top of pipe to bottom of rail 2.6 feet. Power house furnishing

FIG. 8.

this current put in operation November, 1897. Examination made November, 1902; length of time these conditions were in full force to cause the damage, between 4 and 5 years.[1]

The next illustration is one of three sections of a pipe discovered at Reading, Pa., which shows how ruinous is the effect of electrolytic action in some cases. No. 2 was in the ground

FIG. 9.

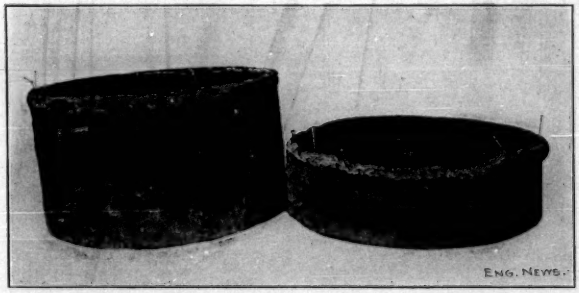
less than one year and nearly eaten through. No. 3 is the one that burst when we were examining it at the railway crossing previously spoken of, the hole being at the left end of the piece, another hole is near the right end.

The next view is a fragment of 6 inch pipe from Brooklyn, N. Y. This burst owing to electrolysis about one year ago was

[1] Through the courtesy of the engineers of the Metropolitan Water Board of the State of Massachusetts, this is shown for the first time in public.

the cause of the waste of a large amount of water which ran off into a canal nearby and did not show on the surface of the street. No one connected with the Water Department can tell how long this water was flowing to waste; the break was discovered by accident, a heavy truck wheel breaking through the ground, which had been hollowed by the force of water flowing away. This pipe was positive to the trolley rails to nearly 6 volts and also plus to a gas pipe in the same street and the water of the canal, indicating current flowing from it in three different directions.

FIG. 10.



The next section of a pipe shown (Fig. 9) is from an 8 inch cast-iron main also taken from a street in Brooklyn. It is made of Scotch iron, one method of identifying which is the bulging rings on each length. One of these rings is shown near the left hand end. At one time it was thought by some that this quality of iron pipe was immune from electrolysis but that idea has long since been proved a fallacy in many cases similar to this.

We will now pass to the other phase of electrolytic action, namely, corrosion of the *joints of mains*, particularly water pipe joints.

The first view (Fig. 10) is from a photo of two ends of a 16 inch water main from Peoria, Illinois, and shows very clearly how the pipe was injured by electrolysis upon the *inside* of the joint. We are informed by Mr. D. H. Maury, consulting engineer in charge of the Water Company, who made this discovery, that of the 1000 feet of this pipe removed from the

ground every joint showed more or less of this action; at some places near the end of the pipe the metal was softened or eaten away for more than an inch.

Two other photographic views (Fig. 11) of this same pipe illustrate electrolytic action upon the *outside* of the main close to the lead packing of the joint; this is indicated by the row of nails driven in on the softened iron, showing the shunting effect of the current; this pipe was taken up owing to a change in pumping works, a new one having been built. We are also informed that at no other place upon this pipe except at the spigot ends were there any signs of electrolysis, the direction of current through the main being from spigot to bell.

FIG. 11.

Fig. 12 is from a photograph of 6 inch pipe from New Bedford, Massachusetts. This had previously lain in the river; it has a ball-and-socket joint, and was in preparation for further use. We discovered during an investigation in that city that a number of the ends were badly softened and much weakened by electrolysis, the nails driven in at some of the soft places show where they were damaged; when the attention of the Superintendent was called to this damage he promptly condemned several lengths as being unfit for further use.

The following view represents a portion of a 6 inch gas main taken while in use at Norristown, Pa., with pittings showing upon the spigot side of the joint; one of them was 3-16 inch in depth, which was on the far side of the pipe and not shown in the view.

We will now give our attention briefly to electrolytic action upon *water meters.*

This part of the subject so far as we know has not before been touched upon. It shows, however, that there are other metals underground besides pipes that are affected by electrolysis; and not the least important among them is water meters.

Two recent meter examinations made by the writer in two different cities revealed the fact that in a number of cases meters were injured by electrolysis; this is owing principally to their

FIG. 12.

location. In many cases to prevent freezing, meters are placed in pits 3 to 4 feet below the surface of the ground, the bottom and sides of the pits boarded up and provided with wooden covering. Some of these are placed under the docks along a river front, and many in the cellars of dwellings and stores.

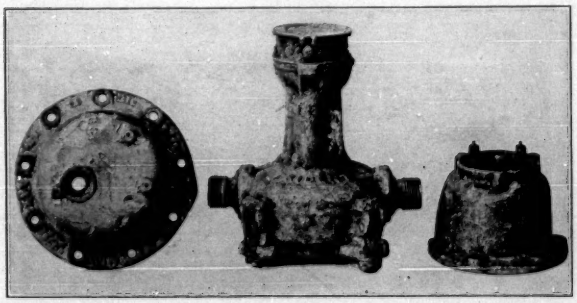
It will be readily seen that in the latter case the meter pit is practically a cess pool, as it is the lowest part of a cellar and collects the drainage of whatever liquids may be upon the cellar bottom, the quality of which will usually make a good electrolyte (and the same will apply to meter pits under stables, in such case there is a large percentage of ammonia in the solution) and

it is well known that this ingredient materially helps electrolytic action.

Fig. 13 is a photograph of the upper parts of two meters and the whole of a third, all showing the effect of electrolysis and the very evident cause of their removal.

At all of the places where meters had been similarly damaged in this investigation, in making tests it was found that those which took their place *positive* to the soil or gas pipe, were the ones damaged. With the usual trolley current variation, such tests were usually made with a millivoltimeter, the readings taken between the meter and an iron bar driven down in the wet soil alongside of the pit, the variations in most cases running

FIG. 13.



from 20 to at times as high as 250 and 300 millivolts. These samples were taken from a number similarly affected.

Another photograph (Fig. 14) shows the under side of a 4 inch meter which was practically destroyed by electrolysis. It was placed in a pit at a ferry house where tide water had access. The potential measurements showed the pipes which had connected with the meter to be positive to nearby trolley rails from 5 to 7 volts. This meter was in use 6 years and 8 months; the under side was softened nearly through the iron, as shown where it has been cut away, and a knife-blade pushed in up to the handle. The fish-trap connected to it had several holes in it, as shown in the next photograph (Fig. 15). The actual loss in weight of iron through electrolysis was carefully ascertained and found to be just *15 pounds*.

In another city where a meter smaller than the above was placed in a pit at a dock and subject to tide water, it was found when the pit was pumped out and an examination made, that the service pipe *on both sides* of the meter had burst owing to electrolysis, the larger leak on the consumer's side explained the cause of abnormally high meter readings as well as the vigorous protests on the part of the consumer when bills were rendered.

The meter was also somewhat damaged. It was found positive to the river, the same as in other cases along the docks. The power house was upon the opposite side of the river, and this current leaving pipes and meters was flowing *across,* as has been illustrated in the map (Fig. 1.)

FIG. 14.

It may seem strange that no better setting of water meters is made than in the places referred to. In many cases, however, where the ground is low, it is practically impossible to keep them dry more than one month in the year, those near tide water being partially or wholly submerged every day in the year. In some cities a better method is used for setting meters, such as placing them in a water-tight iron box below the side-walk in the street, and from the best accounts obtainable freezing is avoided as well as electrolysis.

There is one other view (Fig. 16) which may be interesting in illustrating the effect of electrolytic action upon the partially exposed iron or steel work of bridges, and showing the distinction between ordinary corrosion and electrolytic action. This

does not, of course, refer to underground foundations or cable anchorages, but to the metal work of the shore spans or trusses where the heavy planks of the roadway rest against or nearly against them. Between the planks and the metal is usually lodged the sweepings of the bridge, which consists almost entirely of animal refuse; this will and does cause corrosion where there is no current present, but when current is flowing from the iron to the surrounding soil it passes through this material and to the planks which are often wet and damp. In this particular case, which was of a bridge at Providence, Rhode Island, each one of the four shore ends of the trusses was carefully tested:

FIG. 15.

At three of them no sign of current could be found, and a removal of the planks disclosed but little corrosion; at the fourth however, which is the subject of this photograph, a difference of a potential of from 4 to 6 one-hundredths of a volt was found with the truss positive to the soil.

As will be seen, part of the iron plate of the truss which lay next to the planks was quite badly corroded, the iron which was originally ⅜ inch thick was reduced for a considerable space to about the thickness of paper and penetrated in three places—two of the holes are shown in the photo, the third was discovered after it was taken. This distinction therefore between

[3] Since this paper was delivered this bridge has been replaced by a new one. The underground chords when uncovered were found badly corroded and weakened from electrolysis.

ordinary corrosion of metals and corrosion caused by electrolytic action, we regard as quite marked.[2]

It seems proper that something should be said as to the situation in this city of Philadelphia regarding electrolysis. It has often been asserted that no electrolysis exists here, the reason given owing to the compulsory requirements of an excellent Electrical Bureau. Track returns of heavy copper auxiliaries have been established as well as efficient rail bonding, probably far exceeding in extent and completeness the track returns of any city in this country.

If excellent construction were a guarantee against electrolysis then there should certainly be none here; but as a result of a few tests which we have made for the purpose of getting some

FIG. 16.

idea of the situation we are prepared to say that electrolytic action *is* going on at both water and gas mains in certain quarters of the city, as we will undertake to show.

A measurement for current flow upon a 30 inch cast-iron gas main in the subway, on the south side of Market Street revealed a flow of trolley current west reading at times as high as 12.5 amperes.

In the vicinity of the power house on the west side of the river towards which this current was flowing the potential difference was too high to be measured with the instrument we had at the time, as its limit was but one volt, the needle however went off scale hard, and did not show even a minimum reading. The mains are positive to the rails and it is safe to say that the

reading would not be less than two volts and may reach from four to five volts.

Tests between the water mains and rails in the same vicinity were from 0.3 to 0.7 of a volt, mains positive. From these tests we conclude there may be electrolytic action upon the water mains if they are located in wet soil where the resistance is sufficiently low for some current to pass, but this is not usual with such low difference of potential. There was no opportunity to make a current measurement upon the water mains in this part of the city.

In regard to the gas mains, however, from the current flow discovered on the main in the subway and the tests near the power house, we believe they are being damaged by electrolysis in this vicinity.

Some further tests were made in another part of the city, upon water mains that were found accessible, the most important one being the one in Greenmount Cemetery. Not far from the Bristol Street entrance there is a 48 inch main resting upon a wooden trestle, as it crosses a small valley. Railway current was discovered flowing through this main north, from 20 to 50 amperes. When a current of electricity is found flowing through an important main, if only 5 or 10 amperes, it is well to learn, if possible, where it is coming out, because at such points electrolysis takes place. Such point has been discovered in this case. About ½ mile north of the test in the cemetery this main crosses Wyoming Avenue, upon which is a double-track trolley road. The main was found highly positive to these tracks, indicating this to be the point of delivery for this current, and as the power house is a short distance west, it is most natural for this current to pass out of the main to these tracks and thence to power house.

A number of precedents in similar cases in our own experience justified our prediction, made to the General Superintendent of the Water Bureau that this main was being damaged by electrolysis under these tracks, and it was but a question of time, if these conditions continue, when it would be in grave danger of bursting.

He informed us if such a thing should happen it would cut off the water supply of a large section of the city until it could again be repaired. Another effect would be the heavy cost of

damage to property through the sudden letting loose of a huge mass of water, as well as the heavy cost of repairs. One experience of this kind has recently been had in this city the details of which are well known, and a repetition of such an accident would of course be very undesirable. We are informed that the cause of this break, however, was a defect in the iron of the pipe.

Since we reported these conditions two weeks ago, changes made have considerably improved the situation as further measurements made only to-day show. For instance, instead of 40 to 50 amperes of current discovered flowing *north*, there is now but 5 to 15 amperes, and it is flowing in the reverse direction, *south*. Instead of the main being highly positive to the rails on Wyoming Avenue, as found at that time, it is now negative to the rails, from 3 to 4 volts. Just how much this main is damaged by electrolysis under these tracks depends somewhat on the length of time these conditions were in force before the change was made. It would be interesting to know also where the average current of 10 amperes now flowing south through it is coming out, but lack of time and severe weather have prevented further investigation.

One method used in some cities for relieving mains from electrolysis at badly affected places is to bond them to the rails or railway return. This we have always opposed for the reason that more current flow is invited upon them and electrolytic action takes place at the joints, mostly inside, if a water main, illustrations of which we have shown in several views.

We do not believe it to be good policy where the future is considered to allow either the water or gas piping system in any city to be practically converted into a railway return by bonding and if we understand the situation correctly that is the view taken by the Managers of the Electrical Bureau in Philadelphia.

We have only touched briefly upon various points as to *cause* and *effect* of electrolysis upon underground metals, we will now turn our attention in conclusion to a few remarks as to the prospect of *remedy*.

Under the present system of operating street cars with its "grounded" track return there can be no other result under the law of divided circuits but that more or less railway current will pass to and through underground metals, causing electrolys's

among them in a greater or less degree according to local conditions. This diversion of current from rails to mains is restrained in some cases by liberal use of copper in the auxiliaries, but even then there is sure to be escape at some parts of the system, practical illustrations of which having just been shown.

The late I. H. Farnham, one of the first investigators in electrolysis, stated in a paper read before the Institute of Electrical Engineers in New York in 1894 that—"In some cities where electrolysis is in progress to-day, the return copper nearly equals that of the trolley and feed-wire system. We cannot force a current to take one path exclusively when others are open to it." This statement was made 10 years ago; since then there have been many electric railway lines built, but excepting the double underground trolley in New York and Washington there has been no other system brought into general use than the present single trolley.

The present status therefore as to the *cause* and *effect* of electrolysis does not differ much from the conditions as they existed ten years ago, except there is a tendency for better construction on the part of the railways, which modifies the effects but does not cure the trouble.

In the evolution of the electric railway it is impossible to say if the next step is to be a method which will or will not cause electrolysis. The double trolley has been largely advocated and both the overhead and underground methods have been in practical use for years.

An improved storage battery has been looked to as a possibility. A modification of the gasoline engine as used in automobiles is another possibility. Any of these methods will of course avoid electrolysis. The latest, however, which is attracting considerable attention as a possibility is the alternating current method.

We are not prepared to say what the effect of alternating currents will be. In one case a laboratory experiment showed that the metal was removed from each electrode and deposited between them. If this is to be the result in practice then not much help can be expected from this direction, but it is to be hoped that some system will be evolved that can be operated without a "ground" and will result in finally avoiding electrolysis or corrosion to underground metals.

BOOK NOTICES

SANITATION AND SANITARY ENGINEERING. By Wm. Paul Gerhard, C. E. Second Revised and Enlarged Edition of Sanitary Engineering. vi+175 pages, 5 x 7 inches. Price, $1.50. New York, 1909. Published by the Author.

The enormous development of modern industry in all its branches and, in keeping with it, the ever-growing taste for luxurious surroundings in domestic life with its consequent complexity of means and devices subserving to that end, have given rise to a considerable number of ramifications of engineering science. Where a score of years ago the branches of engineering science might be counted on the five fingers, a score is now nearer their number. Sanitary Engineering is one of the more recent of these. Covering a consideration of the technical problems involved in the maintenance of public health and our creature comforts, its scope is, indeed, a broad one. Mr. Gerhard sets forth the history and present status of sanitation as a legitimate branch of engineering, laying some stress upon the qualifications implied by the title "sanitary engineer." Such timely topics as water supply, sewage, garbage disposal and street cleaning, are included in an interesting account of the actual practice of the sanitary engineer. Under the title of "a half century of sanitation," the development of the science, both home and abroad, is considered. The two final chapters are devoted, the one, to the practice of sanitation in Greater New York, the other, to sanitation in Russia. A bibliography at the end of the volume of the author's own works on this subject is added.

The work covers the ground thoroughly; is written in a fluent and entertaining style, and should well fulfil its evident mission of stimulating a more widespread study of sanitation. L. E. P.

DÉTERMINATION DES ROCHES. Par L. M. Granderye, Docteur de l'Université, Ingénieur-Chimiste. 172 pages, 4½×7½ inches. (Encyclopédie scientifique des Aide-Mémoire.) Price, paper, 2 francs 50; cloth, 3 francs. Gauthier-Villars, Paris, 1908.

The present volume is supplementary to the previous work by the same author, "La Détermination des Espèces Minérales," and covers the same ground in the province of petrology.

Theories and principles involved in rock formation are first given, followed by a treatment of various methods of examination and identification and, finally, an alphabetical list of 250 lithological specimens and a bibliography. L. E. P.

A COURSE IN QUALITATIVE CHEMICAL ANALYSIS OF INORGANIC SUBSTANCES, WITH EXPLANATORY NOTES. By Olin Freeman Tower, Ph.D., xii+83 pages, 6 x 9 inches. Price, $1.00 net. Philadelphia: P. Blakiston's Sons & Co.

In presenting this work the author is mindful of the many other manuals

already in print, and his aim has been not only to overcome their shortcomings, but also to present the subject in accordance with its most modern development.

An outline of the principles of physical chemistry is given in the introduction for convenient reference which should prove useful to those who wish to refresh their knowledge of the subject without referring to an exhaustive treatise. As quantitative analysis deals mainly with substances in solution, ionic formulas are freely used, but when a knowledge of the actual salts is of more importance, molecular formulas are given. Standard methods of separation are employed with a few exceptions which have, under the author's direction, yielded better results in the hands of students.

Notes relating to the procedures described are conveniently arranged on the same or opposite page. There is no index but the detailed table of contents should serve in its stead in a book of this size. L. E. P.